applications $(\frac{N}{3}P)$ sugar beets have much more seedling diseases than when it is divided in two amounts $(\frac{N}{2}P)$, in which case one half of the nitrogen is applied at the time of seeding and the remainder soon after thinning.

3. The plots with unbalanced soil treatments (N, P or M) all had high amounts of seedling diseases; the yields and stands were also poor except for plots with manure.

4. Check plots had the highest amount of seedling diseases, poorest yields and stands.

5. The application of $Ca(OH)_2$ undoubtedly had a beneficial effect in controlling seedling diseases of beets. A comparison of duplicate soil treatments with and without $Ca(OH)_2$ show that all plots with $Ca(OH)_2$ have much less seedling diseases than those without it. It is possible that $Ca(OH)_2$ could have a beneficial effect on the physical, chemical and biological conditions of the heavy clay-loam soil of this region and makes it more suitable for normal development of sugar beets.

In conclusion it may be said that seedling diseases of sugar beets can be efficiently controlled and good stands and high yields of sugar beets obtained by creating conditions in the soil which will promote a rapid and healthful development of young sugar beets through:—

1. Use of complete and balanced fertilization.
2. Improvement of the physical conditions of the soil, and
3. To a limited extent through the seed treatments.

SEEDLING DISEASES, PHOSPHATE DEFICIENCY AND FURARIUM YELLOWS OF SUGAR BEETS IN THE ROTATIONS AT THE HUNTLEY FIELD STATION IN MONTANA[1]

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Seedling diseases of sugar beets which are commonly called "Black root" manifest themselves in the rot of young beet roots. They limit the profitable production of sugar beets in some sugar-beet-growing sections of Montana. Phosphate deficiency is also an improtant physiological disease of sugar beets, especially on heavy alkali soils poor in available phosphates. Fusarium wilt or yellows of sugar beets is important only where sugar beets are planted continuously on the same ground.

During the past four years these diseases of sugar beets were studied in the sugar beet rotations at the Huntley Field Station, which is located at the Yellowstone Valley of Montana in the vicinity of Billings. The results of

[1]Contribution from Montana State College, Agricultural Experiment Station Paper No. 133 Journal Series. Abstract of paper presented at the meeting of the American Society of Sugar Beet Technologists, Denver, Jan. 4-6, 1940

these studies for 1939 are reported for twenty different rotations, the list of which is given in Table I. The following crops are grown in these rotations: alfalfa, sugar beets, potatoes, oats, wheat, beans and corn. These crops are grown continuously and in rotations of 2 to 6 years duration. The rotations provide various sequences with different soil treatments. These experiments were established in 1912 and 1916 to obtain information concerning the most desirable rotations for this part of the country and to determine the value of alfalfa and manure when used in rotations, where the soil is of a heavy clay-loam type. The average rainfall over the twenty year period was 14.27 inches and additional moisture is furnished to the crops by irrigation.

Readings of seedling diseases of sugar beets were usually taken when the seedlings were in the 4 to 6 leaf stage. Samples of one hundred or more taken from each plot were carefully examined for the presence of disease. Four times during each growing period counts of the stand of beets and notes on all beets showing symptoms of phosphate deficiency and fusarium wilt were made in every alternate row in all rotation plots.

TABLE I

List of Irrigated Rotations at the Huntley Field Station

I. Following rotations begun in 1912.
2. Sugar Beets (continuous cropping)
20. Potatoes, Sugar Beets.
21. Potatoes, Sugar Beets. (Manure)
22. Oats, Sugar Beets.
23. Oats, (Manure), Sugar Beets.
30. Potatoes, Oats, Sugar Beets.
31. Potatoes, Oats, (Manure), Sugar Beets.
32. Corn, Oats, Sugar Beets.
40. Potatoes, Sugar Beets, Alfalfa, Alfalfa.
42. Oats, Sugar Beets, Alfalfa, Alfalfa.
60. Potatoes, Oats, Sugar Beets, Alfalfa, Alfalfa, Alfalfa.
61. Potatoes, Oats, (Manure), Sugar Beets, Alfalfa, Alfalfa, Alfalfa.
63. Corn (hogged off), Oats, Sugar Beets, Alfalfa, Alfalfa, Alfalfa (hogged off).

II. Following rotations begun in 1916.
2C. Sugar Beets (continuous cropping). Manure alternate years beginning in 1927.
34. Potatoes, Sugar Beets, Oats.
35. Potatoes, Sugar Beets, Oats, (Manure).
46. Sugar Beets, Oats, Alfalfa, Alfalfa.
64. Potatoes, Sugar Beets, Oats, Alfalfa, Alfalfa, Alfalfa.

In addition to these rotations there are:

2B Sugar Beets (Manure) (Continuous cropping). This rotation was started in 1928.

0 in Maximum Production Experiment.

This rotation has potatoes, beets, wheat, corn, oats, beans and several years of alfalfa. Phosphate applied to beets each year since 1930. Manure was applied to all cultivated crops and alfalfa.

The graph for 1939 (Fig. 1) is quite typical for the general disease situation in sugar beet rotations since 1936. A comparison can be made in this graph between the amounts of diseases, the yield and the stand of sugar beets in each particular rotation. Also the effect of the other crops in the rotations on the development of the diseases and how they effect the yield and stand of beets can be compared by studying the different rotations.

Seedling Diseases

All unmanured rotation plots, namely; 2, 20, 22, 34, 40, 42, 46, 60 and 64 had considerable more seedling diseases than manured plots 2B, 2C (which had considerable amount of seedling diseases in 1939) and plots 21, 23, 31, 35, 61, 63 and O. The only exceptions to this were the two unmanured three-year rotations, 30 and 32 which had a small amount of seedling diseases. The soil of these plots which is somewhat lighter than the rest of the field possibly accounts for this fact. These results show that manure has quite a beneficial effect in reducing seedling diseases and increasing the yield of sugar beets. It is possible that manure by increasing the vigor of sugar beet seedlings makes them more resistant to disease and it may also have an indirect effect by supporting the development of saprophytic soil organisms which through competition can reduce the number of parasitic organisms in the soil.

All rotations with alfalfa and without manure had a very high amount of seedling diseases and phosphate deficiency, especially so when sugar beets were planted immediately after alfalfa (i. e. rotation 46). It is difficult to explain this situation, but still several factors could be mentioned.

1. An old alfalfa ground, under the conditions of dry weather in fall and hard frost in winter, most of the alfalfa remnants overwinter in the soil without much decomposition, a situation which makes it very difficult to prepare a good seed bed.

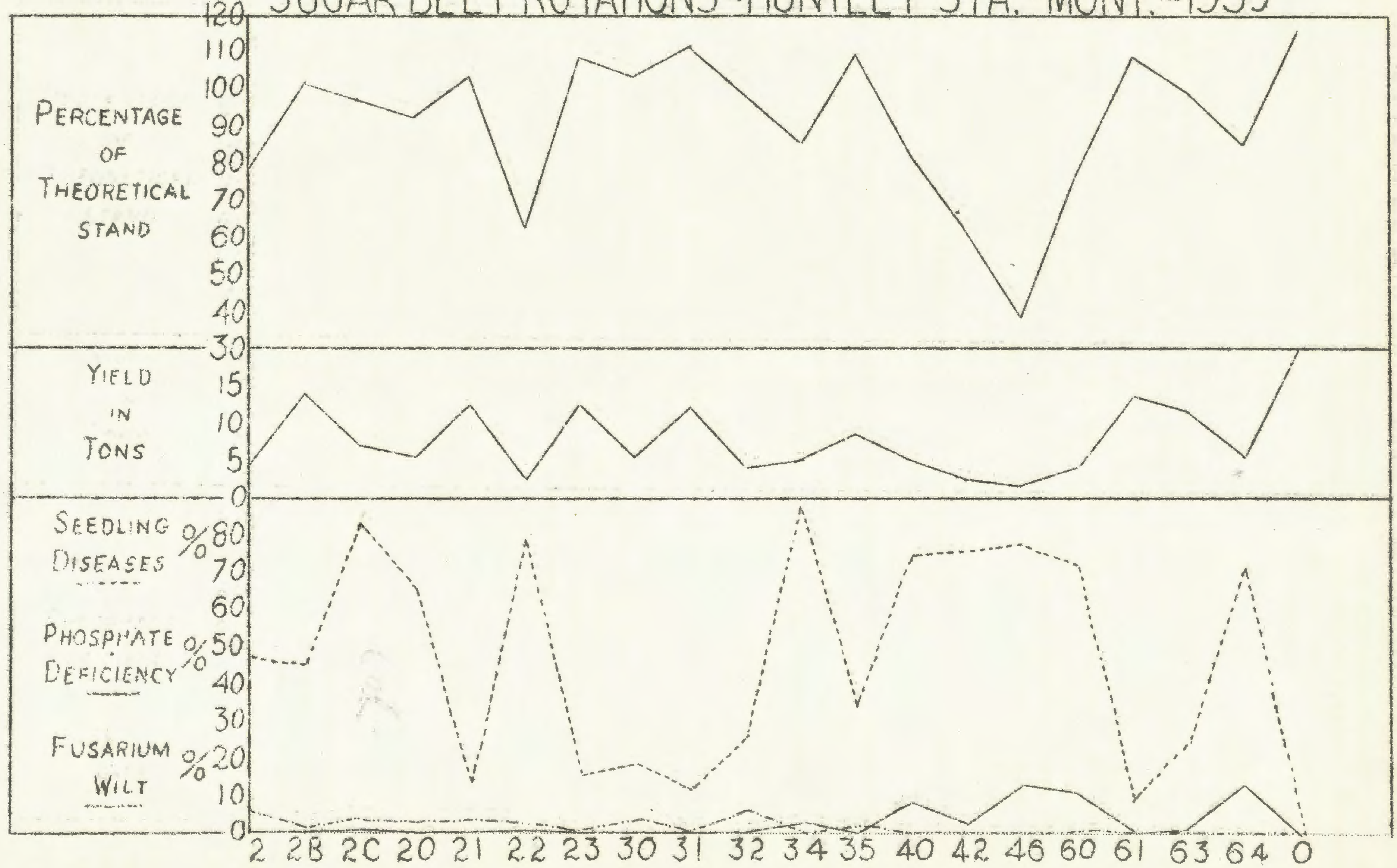
2. The main decomposition of alfalfa remnants begins only with the moist warm spring weather which closely coincides with the germination and growth of sugar beet seedlings. Fungi are the first soil agents attacking plant materials, paving the road for bacteria and actinomyces. Because most of our seedling diseases of sugar beets are caused by fungi, the condition favorable for the optimal development of fungi will be also favorable for the development of diseases, at least from the standpoint of the abundance of inoculum. Alfalfa ground should preferably be plowed in mid-summer, then irrigated to favor decomposition of alfalfa remnants during the current season.

3. In the rotations with alfalfa the soils are deficient in available phosphates. Alfalfa is a very heavy feeder of phosphates, so after cropping for several years, the soil is depleted in available phosphates while at the same time, alfalfa leaves the soil enriched with nitrogen, which unbalances the ratio between nitrogen and phosphates as compared to non-leguminous crops. With unbalanced and deficient nutrient in the soil, sugar beets grow slowly, which condition is very favorable for the development of seedling diseases.

Phosphate Deficiency

All unmanured plots with alfalfa in the rotations and especially those where beets are planted immediately after alfalfa, show the greatest phosphate deficiency. This may be due, not so much to an actual phosphate deficiency in the soil, as in an unbalanced relationship between the very low amount of avail-

SUGAR BEET ROTATIONS - HUNTLEY STA. - MONT. - 1939



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able phosphates and a surplus of nitrogen. As evidence of this beet rotations with alfalfa always show more symptoms of phosphate deficiency than those in continuous beets or in two year rotations which have a very low amount of phosphates and nitrogen in the soil. Rotations with alfalfa and manure show very little phosphate deficiency.

Fusarium Wilt

Fusarium wilt or yellows occur mostly in one, two, and three year rotations. Three year rotations on the lighter soils always have much wilt, while the four and six year rotations are practically free of wilt.

APHANOMYCES ROOT ROT OF SUGAR BEETS AS INFLUENCED BY PHOSPHATE APPLICATION.

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It is known that species of Aphanomyces, especially A. cochlioides Drechsler cause damping-off of sugar beets and, with older plants, death of lateral rootlets. These effects have been confirmed in experiments at Arlington, Va., as well as in field experiments in Ohio and Michigan. Isolations made from sugar beet plants in which the terminal portion of the tap roots were blackened and killed have shown that a species of Aphanomyces, tentatively assigned to A. cochlioides, is associated with this condition. The rotting usually extends up from the terminal of the root about one-quarter to one-half of its length but may involve the entire root.

General field observations had indicated a probable association of this disease with relatively wet soil conditions. Observations made in experimental plots in Michigan and Ohio, have shown that killing of lateral rootlets of the sugar beet, and the dwarfing of plants from this cause was prevented by application of fertilizers high in phosphate. In the plots in which such observations were made, tip rotting of the beet tap roots were absent where phosphate was applied, but common in untreated plots and in untreated borders.

An experiment was conducted with sugar beets grown from seed in quartz-sand cultures to test the protective effect of phosphate applications against Aphanomyces attack under conditions of optimum and high water levels. The exposure was secured by uniformly inoculating 3-gallon culture jars of autoclaved quartz-sand plus nutrient solution five days before the seed was planted with (a) a pure culture of A. cochlioides or with (b) plant debris and sand from a previous experiment in which Aphanomyces as well as other root rotting organisms occurred. The experiment was started with the numerous seedlings obtained from planting 50 seed balls in each jar and then after 46 days, each jar was thinned to five plants evenly spaced to be carried for an additional period of 132 days. The seedling at approximately the proper distance from its neighbors which appeared most likely to live was left when the jars were thinned. For the most part, this thinning approximated field practice in which the best plant in a clump at approximately the right position in the row is left.

Abundant previous experience had shown that sugar beets could be grown over long periods in nutrient solution, quartz-sand cultures without damping-off or root decay occurring. An observation set of quartz-sand cultures was used in this test. The seedlings in the check cultures without organisms remained healthy. At the close of the experiment plants in the check cultures were free from root rot.

For each type of inoculum, half of the cultures was grown using a nutrient solution high in phosphate, and the other half was started with a nutrient solution without phosphate. After thinning, complete nutrient solution was occasionally used with the jars in which phosphate was to be held minimal, otherwise these jars received nutrient solution without phosphate. As a rule, throughout the experiment, 200 cc of the respective nutrient solutions were added twice a week to the appropriate culture jars. It was found that this amount was enough to bring about discharge or overflow from the jars. Tap water was added at other times as needed to prevent wilting.

For the contrasts in water level, half of the jars for each phosphate condition were equipped with siphons to prevent water standing in the jars, and the others had 5-inch stand pipes which kept the sand in the lower portions of the jars more or less water-logged.

The cultures were grown throughout the test on rotating tables to equalize light and temperature conditions. Each treatment was replicated 10 times and the results are given as 10-culture averages in Table 1 for the seeding phase. In Table 2 the results are given as sums of the 10 replicates for each treatment after 178 days.

The following conclusions were drawn from the experiment: Increase of mortality in seedlings and in larger plants was shown in the cultures with minimal phosphate nutrition as compared with those cultures grown under conditions of higher phosphate nutrition. The water level relations were over-shadowed by the nutritional effects, but some evidence is afforded that the mortality of seedlings is greater when water level is high and that Aphanomyces attack on the tap root may be increased.

The conditions set up in the experiment represent extremes, but are not entirely outside of those found in the field. Taken in connection with the field observations, they point to a definite relationship between severity of Aphanomyces attack and phosphate deficiency.

Table 1. --Numbers of apparently healthy sugar-beet seedlings remaining in quartz sand cultures after 7- and 46-day exposures to pure cultures of Aphanomyces cochlioides and organisms from debris of diseased plants. High phosphate is contrasted with minimal phosphate under conditions of optimum and high water levels. (Results given as 10-culture averages.)

Inoculum	Phosphate	Water Level	Apparently healthy 1/ sugar beet seedlings after-- 7 days	46 days
A. cochlioides (pure culture)	High	Optimum	79.0	32.1
do.	do.	High	68.8	17.2
do.	Minimal	Optimum	77.3	0.4
do.	do.	High	79.0	0.5
Debris from diseased plants	High	Optimum	87.8	73.6
do.	do.	High	91.8	62.0
do.	Minimal	Optimum	90.6	8.5
do.	do.	High	90.8	3.0

1/ As judged by absence of top symptoms or discolored hypocotyls.

Table 2.— Record of sugar beet plants following exposure to Aphanomyces cochlioides and to organisms from debris of diseased plants: Cultures shown in table 1 were thinned to five plants each after 46 days and continued on rotating tables for 132 days. Results are given as sums of the 10 cultures in each treatment.

Treatment			No. of plants after thinning	Results after 178 days			
				Condition of tap roots			
Inoculum	Phosphate	Water Level		Sound	*A. cochlioides* rot	Other types of rot	Dead
A. cochlioides (pure cultures)	High	Optimum	50	50	0	0	0
do.	do.	High	50	39	0	7	4
do.	Minimal	Optimum	50	25	9	0	16
do.	do.	High	50	28	13	0	9
Debris from diseased plants	High	Optimum	50	37	2	11	0
do.	do.	High	50	43	1	6	0
do.	Minimal	Optimum	50	35	6	0	9
do.	do.	High	50	21	7	0	22