THE EFFECT OF SOIL TREATMENTS ON THE INCIDENCE OF BLACK ROOT IN SUGAR BEETS

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A. W. McAllister

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THESIS

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The Effect of Soil Treatments on the Incidence of Black Root In Sugar Beets

A. W. McAllister

Introduction

Black root disease is probably the most common and widespread of all sugar beet diseases in Michigan (7). Up to the present time no treatment has been found that will consistently control the trouble under Michigan conditions. The object of this investigation was to find some method applicable in the control of this disease.

Review of Literature

Very little information is available concerning the effect of soil treatments on the control of seedling diseases of sugar beets which refers especially to black root.

Afanasiev (1) (2) reported that plants in well fertilized plots suffered less injury due to seedling diseases than plants growing in check plots, and that calcium hydroxide applications were beneficial in seedling disease control. He suggested that the lime had a beneficial effect on the physical and biological conditions of heavy clay soil thus making growth conditions more favorable for the seedlings.

Campbell (3) found that borax and lime or a mixture of these materials gave some indication of being effective in the control of black root but the amount and method of application for best control had still not been decided.

Kotila and Coons (5) (6) reported that a heavy application of phosphate was helpful in the control of black root.

Procedure

The results reported in this paper were obtained from both greenhouse and field experiments.

Greenhouse Experiments

The greenhouse work was conducted as follows. Treatments were applied to jars of soil inoculated with a pure culture of Rhizoctonia solani* grown in a cornmeal medium. This culture was made by inoculating a two inch layer of cornmeal in the bottom of an 800 cc erlenmyer flask with the organism and allowing the contents of the flask to incubate until the entire medium was attacked by the organism.

Two soils, a Brookston silt loam and a Miami silt loam were used in the greenhouse experiments.

Four replications of thirteen treatments were set up in two gallon earthenware jars for each of the soil types, making a total of 104 jars. Nine kilograms of the Miami soil per jar were used, and eight kilograms per jar of the Brookston soil.

The thirteen treatments were as follows:

Treatment 1. R. solani

Treatment 2. R. solani, sterilized

Treatment 3. R. solani + 4-16-8

Treatment 4. R. solani, sterilized + 4-16-8

Treatment 5. R. solani + 4-16-8 + alfalfa

Treatment 6. R. solani + 4-16-8 + manure

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*This culture was obtained from Mrs. F. C. Strong, Assistant in Research in Plant Pathology, Botany Department, Michigan State College.

Treatment 7. R. solani + 4-16-8 + manure + P_2O_5 + Mn + Cu + B

Treatment 8. R. solani + 4-16-8 + P_2O_5 + Mn + Cu + B

Treatment 9. R. solani + 4-16-8 + alfalfa + P_2O_5 + Mn + Cu + B

Treatment 10. R. solani + 4-16-8 + alfalfa + Mn + Cu + B

Treatment 11. R. solani + 4-16-8 + alfalfa + P_2O_5 + Cu + B

Treatment 12. R. solani + 4-16-8 + alfalfa + P_2O_5 + Mn + Cu

Treatment 13. R. solani + 4-16-8 + alfalfa + P_2O_5 + Mn + B

The rate of application of the 4-16-8 was 600 pounds per acre and the fertilizer consisted of a mixture of C. P. KNO_3, $(NH_4)_2SO_4$, and $Ca(H_2PO_4)_2 \cdot H_2O$.

The alfalfa was second cutting, finely ground and applied at the rate of twenty tons per acre of air dry material.

Finely ground horse droppings at the rate of five tons of dry material per acre were used as the source of manure.

A twenty-five gram portion of R. solani cornmeal culture was thoroughly mixed with the top three inches of soil in each jar.

The phosphorus, manganese, boron, and copper were applied as C. P. $Ca(H_2PO_4)_2 \cdot H_2O$, $MnSO_4 \cdot 2H_2O$, $Na_2B_4O_7 \cdot 10H_2O$, and $CuSO_4 \cdot 5H_2O$ in solution at the rate of 200, 60 , 30, and 40 pounds per acre of these materials respectively.

The following method of preparing the treatments was used. The 4-16-8 fertilizer and the organic materials were thoroughly mixed with the soil for each jar in a mechanical soil mixer (3) and then distilled water was added to the soil until optimum moisture conditions were reached. The mixed soil, fertilizer, and organic materials were then returned to the jar and the top three inches removed again and thoroughly mixed by

by hand with a 25 gram portion of the cornmeal culture of R. solani. This material was then restored to the jar and allowed to stand for one week thus permitting the organism to become established in the soil.

The solutions containing the borax, manganese sulfate, and copper sulfate were then added and two days later the $Ca(H_2PO_4)_2 \cdot H_2O$ solution was added.

The jars were planted with twenty-five seed balls of U. S. 200x215 sugar beet seed, soaked in distilled water twelve hours before planting. The seed was evenly spaced by using a perforated cardboard in planting. The planting was made April 8, 1941 and counts of the number of seedlings damped off were made at four different times, May 4, June 2, July 1, and August 21.

Field Experiments

The field experiments were located on two different soil types; a Conover loam soil with a pH of 7.0 on the Earl Foss farm, Sanilac county, Michigan and a Wisner clay loam soil with a pH of 7.5 on the Steve Wiergorski farm, Tuscola county, Michigan. On the Foss farm alfalfa on which 10 loads of barnyard manure had been applied during the winter of 1941 was plowed down for the sugar beets. On the Wiergorski farm the sugar beets followed a field bean crop.

Six treatments, as shown below, replicated four times in a randomized block arrangement were applied at each of the two locations.

Treatments* Applied to Plots in Field Experiments.

Treatment number	2-16-8	0-20-0	$CuSO_4$	$MnSO_4$	Borax	Nature of treatment
1	150 lbs.	----	----	----	----	control
2	150 lbs.	200 lbs.	60 lbs.	100 lbs.	10 lbs.	complete
3	150 lbs.	200 lbs.	60 lbs.	100 lbs.	----	B
4	150 lbs.	200 lbs.	60 lbs.	----	10 lbs.	Mn
5	150 lbs.	200 lbs.	----	100 lbs.	10 lbs.	Cu
6	150 lbs.	----	60 lbs.	100 lbs.	10 lbs.	P_2O_5

*Rates expressed as pounds per acre.

The fertilizer materials were applied in a band one inch to the side and one and one-half inches below the seed. The plots were two rows x 100 feet long with a row spacing of 24 inches. U. S. 200x215 seed was used at the rate of 12 pounds per acre.

The data secured from these experiments included stand counts, yield, incidence of heart rot symptoms, effect of treatments on damping off, % sucrose, and % apparent purity.

All data were subjected to statistical treatment by the analysis of variance.

Discussion

Greenhouse experiments: In order to determine the effectiveness of the inoculation method two treatments were set up with a sterilized culture of the R. solani, one of the treatments receiving no fertilizer and the other the 600 pound application of 4-16-8. The incidence of black root in the seedlings grown in these jars would indicate whether or not

there were other organisms present in the soils responsible for black root injury and also would be indicative of the effect of the twenty-five gram portion of the corn meal culture medium on the occurrence of black root in the sugar beet seedlings. The data in Table 1 definitely show that no black root injury was present in any jar to which the sterilized culture was added and that the corn meal medium had no effect on damping off of seedlings.

The idea has been advanced (6) that black root injury is more prevalent in fields that have had a large amount of green organic matter plowed down and there is a divided opinion among a large number of growers as to whether or not black root injury will show up more if beets are planted after alfalfa or on land receiving a heavy manure application just prior to planting the sugar beet crop. For this reason the alfalfa and manure were used in the greenhouse experiments as the sources of organic matter.

The manganese, copper, phosphorus, and borax treatments were included in the experiment for the purpose of determining whether or not any of these materials would be effective in the control of black root.

A summary of the statistical analysis of the data contained in Tables 2, 3, 4, and 5 is presented in Tables 6 and 7. An examination of the data in these tables, with the exception of those taken July 1, for Miami soil, does not indicate any significant effect due to treatment. In the one exceptional case the "F" value ascribed to treatment was significant at the 5% level. It is clearly evident from the data that none of the treatments was effective in the control of black root under the conditions existing during the period that the experiment was performed. Although the F values for treatment with one exception were not significant the

difference required for significance was calculated and reported with the idea in mind that this value might be of some help in the evaluation of the data. The "F" values for treatment in a number of the cases did approach significance at the 5% level and for this reason the difference required for significance is used in this discussion of results admitting that this procedure is not permissible from the results of the statistical analysis.

Considering the data from the Miami soil at the completion of the experiment with one exception all the cultures containing alfalfa had the highest incidence of black root. All of the cultures that included manure had approximately the same per cent of black root infection as occurred on the jars which received R. solani alone. The lowest per cent infection was in the culture receiving the 4-16-8, Mn, Cu, P, and borax with neither the alfalfa nor manure included. If we were to use the difference required for significance all of the cultures including alfalfa, with one exception (4-16-8, alfalfa, B, Cu, Mn, and P), had a higher per cent of black root infection than occurred in the jars receiving (4-16-8, B, Cu, Mn, and P). This result might be interpreted as indicating that alfalfa if incorporated in the soil may increase the incidence of black root in sugar beets.

The data at the conclusion of the experiment on Brookston soil do not indicate that alfalfa incorporated in the soil has any effect on the incidence of black root. On the other hand, no combination of materials applied to the soil served as an effective means of controlling the black root organism.

The data indicate that the black root organism may attack sugar beet

seedlings any time from seedling emergence for the duration of the experiment, 135 days.

The data in Table 8 bring out the fact that black root injury was significantly greater on the Miami soil than on Brookston soil.

The fact that the occurrence of black root on Brookston soil was most prevalent in the cultures receiving the treatment (4-16-8, alfalfa, B, Cu, Mn) might suggest that applied phosphorus may be an important factor under some conditions in the control of black root.

Field experiments: There was no evidence of black root occurrence at any time during the growing season in the two fields on which the experiments were located and therefore no information regarding the effectiveness of any of the soil treatments on the control of black root was obtained.

However, positive results were obtained from the experiment located on the Wiergorski farm on the effectiveness of borax as a control for heart rot caused from a lack of boron in the soil. An average increase of 5.8 tons of sugar beets per acre resulted from the use of a ten pound application of borax per acre. This application of borax significantly decreased the number of plants showing boron deficiency symptoms from 95.2 percent to 19.4 percent.

It should be remembered that the heart rot caused from the lack of boron in the soil is an entirely different condition than the so-called black root caused by various organisms.

Conclusions

Experiments were conducted both in the greenhouse and in the field

on the effect of soil treatments on the control of black root in sugar beet seedlings. Alfalfa, manure, copper, manganese, boron, a heavy phosphate application and a complete fertilizer were used to ascertain the effect of each of these materials on the occurrence of black root in sugar beet seedlings.

A pure culture of Rhizoctonia solani served to inoculate the soil in the jars used in the greenhouse.

None of the treatments used was effective in the control of black root under conditions existing in the greenhouse during the course of the experiment.

The incidence of black root was significantly higher in the Miami soil than in the Brookston soil.

No black root injury occurred in either of the field experiments. However, the effectiveness of borax as a control of heart rot, due to lack of boron in the soil, was clearly demonstrated.

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Table 1. The effect of sterilization of Rhyzoctonia solani cultures on the incidence of black root.

Treatment	Number of plants infected with black root							
	Miami silt loam				Brookston silt loam			
	B1	B2	B3	B4	B1	B2	B3	B4
R. solani, sterilized	0	0	0	0	0	0	0	0
R. solani, sterilized + 600 pounds of 4-16-8 per acre	0	0	0	0	0	0	0	0

Table 2. The effect of organic matter, phosphorus, boron, copper, and manganese on the incidence of black root due to Rhizoctonia solani from planting time to May 4.*

Treatment			Miami silt loam					Brookston silt loam				
Fert.	O. M.	Additional elements	B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
none	---	----	40.0	15.8	20.0	51.5	31.8	0.0	20.7	13.8	28.6	15.8
4-16-8	---	----	69.2	41.2	34.5	51.6	49.1	6.9	0.0	13.8	51.7	18.1
4-16-8	alfalfa	----	37.5	55.6	28.6	44.8	41.6	0.0	0.0	13.8	10.3	6.0
4-16-8	manure	----	53.8	43.3	31.0	31.0	39.8	0.0	3.4	31.0	5.6	10.0
4-16-8	alfalfa	B,Cu,Mn,P	21.4	27.6	43.8	24.0	29.2	6.9	0.0	6.9	0.0	3.5
4-16-8	alfalfa	B,Cu,Mn	37.5	4.0	26.5	61.3	32.3	10.3	6.9	10.3	37.9	16.4
4-16-8	alfalfa	B, Cu, P	26.7	5.4	39.1	39.1	27.6	3.4	0.0	10.3	25.7	9.9
4-16-8	alfalfa	B, Mn, P	20.0	9.4	15.0	16.7	15.3	0.0	3.4	0.0	13.8	4.3
4-16-8	alfalfa	Cu,Mn,P	30.8	38.7	31.0	23.5	31.0	17.2	10.7	10.3	17.5	13.7
4-16-8	manure	B,Cu,Mn,P	13.8	31.8	13.8	22.2	20.4	6.9	10.3	6.9	6.9	7.8
4-16-8	---	B,Cu,Mn,P	53.3	13.8	12.0	8.0	21.8	3.4	0.0	15.2	10.3	7.2

*Per cent of plants infected with black root.

Table 3. The effect of organic matter, phosphorus, boron, copper, and manganese on the incidence of black root due to Rhizoctonia solani from planting time to June 2.*

Treatment			Miami silt loam					Brookston silt loam				
Fert.	O. M.	Additional elements	B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
none	---	----	100.0	89.5	36.0	93.9	79.9	31.0	65.5	58.6	81.0	59.0
4-16-8	---	----	100.0	94.1	89.7	96.8	95.2	75.9	27.6	24.1	100.0	56.9
4-16-8	alfalfa	----	100.0	96.3	100.0	100.0	99.1	34.5	10.3	58.6	31.0	33.6
4-16-8	manure	----	92.3	96.7	65.5	65.5	80.0	41.4	24.1	51.7	55.6	43.2
4-16-8	alfalfa	B,Cu,Mn,P	71.4	65.5	100.0	92.0	82.2	27.6	24.1	24.1	10.3	21.5
4-16-8	alfalfa	B,Cu,Mn	100.0	88.0	100.0	100.0	97.0	48.3	62.1	51.7	71.9	58.5
4-16-8	alfalfa	B,Cu,P	73.3	100.0	87.0	100.0	90.1	13.8	44.8	34.5	77.1	42.6
4-16-8	alfalfa	B,Mn,P	68.6	100.0	100.0	83.3	88.0	41.4	37.9	37.9	62.1	44.8
4-16-8	alfalfa	Cu,Mn,P	92.3	93.5	100.0	100.0	96.5	24.1	67.9	20.7	60.2	43.2
4-16-8	manure	B,Cu,Mn,P	58.6	90.9	48.3	83.3	70.3	31.0	72.4	41.4	51.7	49.1
4-16-8	---	B,Cu,Mn,P	100.0	65.5	40.0	40.0	61.4	31.0	51.7	81.8	69.0	58.4

*Per cent of plants infected with black root.

Table 4. The effect of organic matter, phosphorus, boron, copper, and manganese on the incidence of black root due to Rhizoctonia solani from planting time to July 1.*

Treatment			Miami silt loam					Brookston silt loam				
Fert.	O. M.	Additional elements	B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
none	---	----	100.0	89.5	40.0	93.9	80.9	44.8	75.9	65.5	85.7	68.0
4-16-8	---	----	100.0	100.0	89.7	100.0	97.4	82.8	37.9	34.5	100.0	63.8
4-16-8	alfalfa	----	100.0	100.0	100.0	100.0	100.0	41.4	20.7	62.1	52.6	44.2
4-16-8	manure	----	100.0	96.7	65.5	69.0	82.8	41.4	41.4	58.6	61.1	50.6
4-16-8	alfalfa	B,Cu,Mn,P	100.0	69.0	100.0	100.0	92.3	31.0	41.4	37.9	10.3	30.2
4-16-8	alfalfa	B,Cu,Mn	100.0	100.0	100.0	100.0	100.0	69.0	75.9	75.9	93.8	78.7
4-16-8	alfalfa	B,Cu,P	100.0	100.0	100.0	100.0	100.0	17.2	62.1	62.1	85.7	56.8
4-16-8	alfalfa	B,Mn,P	85.7	100.0	100.0	100.0	96.4	65.5	55.2	41.4	72.4	58.6
4-16-8	alfalfa	Cu,Mn,P	100.0	100.0	100.0	100.0	100.0	34.5	100.0	44.8	70.6	62.5
4-16-8	manure	B,Cu,Mn,P	62.1	95.5	55.2	83.3	74.0	34.5	75.9	44.8	65.5	55.2
4-16-8	---	B,Cu,Mn,P	100.0	82.8	60.0	40.0	70.7	37.9	55.2	87.9	79.3	65.1

*Per cent of plants infected with black root.

Table 5. The effect of organic matter, phosphorus, boron, copper, and manganese on the incidence of black root due to Rhizoctonia solani from planting time to August 21.*

Treatment			Miami silt loam					Brookston silt loam				
Fert.	O. M.	Additional elements	B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
none	---	----	100.0	100.0	40.0	93.9	83.5	44.8	75.9	72.4	100.0	73.3
4-16-8	---	----	100.0	100.0	89.7	100.0	97.4	93.9	41.4	44.8	100.0	70.0
4-16-8	alfalfa	----	100.0	100.0	100.0	100.0	100.0	65.5	44.8	93.1	62.1	66.4
4-16-8	manure	----	100.0	100.0	69.0	69.0	84.5	58.6	41.4	65.5	66.7	58.4
4-16-8	alfalfa	B,Cu,Mn,P	100.0	69.0	100.0	100.0	92.3	37.9	55.2	48.3	24.1	41.4
4-16-8	alfalfa	B,Cu,Mn	100.0	100.0	100.0	100.0	100.0	79.3	89.7	93.1	100.0	90.5
4-16-8	alfalfa	B,Cu,P	100.0	100.0	100.0	100.0	100.0	27.6	79.3	62.1	100.0	67.3
4-16-8	alfalfa	B,Mn,P	100.0	100.0	100.0	100.0	100.0	89.7	72.4	51.7	79.3	73.3
4-16-8	alfalfa	Cu,Mn,P	100.0	100.0	100.0	100.0	100.0	41.4	100.0	51.7	78.3	67.8
4-16-8	manure	B,Cu,Mn,P	75.9	100.0	65.5	93.5	83.7	34.5	79.3	48.3	72.4	58.6
4-16-8	---	B,Cu,Mn,P	100.0	89.7	60.0	44.0	73.4	65.5	82.8	90.9	79.3	79.6

*Per cent of plants infected with black root.

Table 6. Analysis of variance for per cent of plants infected with black root on Miami silt loam soil.

Date	Source	DF	SS	MS	F	Difference required for significance between any two treatment means.
May 4	Total	43	10,715.22			
	Blocks	3	916.48	305.49		
	Treatments	10	3,921.76	392.18	2.00	20.2
	Error	30	5,876.98	195.89		
June 2	Total	43	15,089.06			
	Blocks	3	681.12	227.04		
	Treatments	10	5,772.90	577.29	2.01	24.5
	Error	30	8,635.04	287.83		
July 1	Total	43	12,370.33			
	Blocks	3	1,045.78	348.59		
	Treatments	10	5,051.62	505.16	2.42*	20.9
	Error	30	6,272.93	209.09		
August 21	Total	43	10,642.05			
	Block	3	1,279.65	426.55		
	Treatments	10	3,564.85	356.49	1.84	20.1
	Error	30	5,797.55	193.25		
Value of F required for significance, 5% point						2.18

*Significant at the 5% level.

Table 7. Analysis of variance for per cent of plants infected with black root on Brookston silt loam soil.

Date	Source	DF	SS	MS	F	Difference required for significance between any two treatment means.
May 4	Total	43	5,217.37			
	Blocks	3	1,466.92	488.97		
	Treatments	10	1,031.92	103.19	1.14	13.7
	Error	30	2,718.53	90.61		
June 2	Total	43	19,958.65			
	Blocks	3	3,522.88	1174.29		
	Treatments	10	5,548.36	554.84	1.53	19.1
	Error	30	10,887.41	362.91		
July 1	Total	43	21,171.95			
	Blocks	3	3,527.65	1175.88		
	Treatments	10	6,632.60	663.26	1.81	19.2
	Error	30	11,011.70	367.06		
August 21	Total	43	20,574.83			
	Blocks	3	2,350.80	783.60		
	Treatments	10	6,404.00	640.40	1.63	19.8
	Error	30	11,820.03	394.00		
Value of F required for significance, 5% point						2.18

Table 8. Complete analysis of variance for per cent of plants infected with black root from the combined data for the two different soil types.

Source	DF	SS	MS
Total	87	44,329.44	
Blocks	3	1,330.25	443.41
Soils	1	13,112.56	13,112.56*
(a) Blocks x Soils	3	2,300.20	766.73
Treatments	10	5,377.52	537.75
Treatments x Soils	10	4,591.33	459.13
(b) Error	60	17,617.58	293.63

*Significant at 5% level.

Table 9. The effect of phosphorus, boron, copper, and manganese on the yield of sugar beets.

Treatment*					Yield - Tons per acre									
					Wiergorski farm					Foss farm				
					B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
2-16-8	--	-	-	--	7.9	8.3	8.9	9.0	8.5	9.5	12.2	11.4	10.7	11.0
2-16-8	Cu	B	P	Mn	14.9	15.7	15.5	11.9	14.5	7.9	8.8	9.4	10.2	9.1
2-16-8	--	B	P	Mn	18.8	11.8	14.2	15.2	15.0	10.1	11.6	11.5	10.8	11.0
2-16-8	Cu	-	P	Mn	7.7	10.4	8.5	8.6	8.8	12.3	9.7	8.4	8.8	9.8
2-16-8	Cu	B	-	Mn	12.1	14.1	13.9	13.0	13.3	7.9	11.8	8.7	11.2	9.9
2-16-8	Cu	B	P	--	15.2	13.4	14.7	16.5	15.0	8.2	12.1	11.6	9.3	10.3

*Rates per acre. 2-16-8, 150 pounds; 0-20-0, 200 pounds; borax, 10 pounds; $CuSO_4$, 60 pounds; $MnSO_4$, 100 pounds.

Analysis of Variance.

Source	Wiergorski farm			Foss farm		
	DF	SS	MS	DF	SS	MS
Total	23	232.26		23	49.41	
Blocks	3	0.90	0.30	3	6.84	2.280
Treatments	5	185.38	37.08**	5	8.89	1.778
Error	15	45.98	3.07	15	33.68	2.245
Difference required for significance			2.64			

**Significant at 1% level.

Table 10. The effect of phosphorus, boron, copper, and manganese on the stand of sugar beets.

Treatment*					Stand - Plants per 200 feet of row									
					Wiergorski farm					Foss farm				
					B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
2-16-8	--	-	-	--	171	187	191	188	184	214	183	179	193	192
2-16-8	Cu	B	P	Mn	166	190	199	188	186	176	167	154	183	170
2-16-8	--	B	P	Mn	190	154	167	205	179	211	156	173	162	176
2-16-8	Cu	-	P	Mn	175	185	169	195	181	189	197	196	181	191
2-16-8	Cu	B	-	Mn	180	199	178	192	187	202	154	180	195	183
2-16-8	Cu	B	P	--	182	175	168	193	180	182	181	199	182	186

*Rates per acre. 2-16-8, 150 pounds; 0-20-0, 200 pounds; borax, 10 pounds; $CuSO_4$, 60 pounds; $MnSO_4$, 100 pounds.

Analysis of Variance.

Source	Wiergorski farm			Foss farm		
	DF	SS	MS	DF	SS	MS
Total	23	3666		23	6299	
Blocks	3	977	326	3	1612	537
Treatments	5	237	47	5	1520	304
Error	15	2452	163	15	3167	211

Table 11. The effect of phosphorus, boron, copper, and manganese on the % sucrose in sugar beets.

Treatment*					Wiergorski farm					Foss farm				
					B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
2-16-8	--	-	-	--	13.9	14.7	14.8	14.2	14.4	15.6	17.0	15.9	15.8	16.1
2-16-8	Cu	B	P	Mn	14.9	14.8	13.9	14.3	14.5	16.6	16.2	16.2	16.0	16.3
2-16-8	--	B	P	Mn	15.3	15.3	14.0	15.5	15.0	15.5	15.6	16.9	15.8	15.9
2-16-8	Cu	-	P	Mn	13.2	15.1	14.2	14.5	14.3	15.5	16.0	16.1	14.9	15.6
2-16-8	Cu	B	-	Mn	15.6	15.6	14.2	14.9	15.1	15.7	16.2	15.4	16.1	15.8
2-16-8	Cu	B	P	--	15.6	14.6	14.3	14.3	14.6	16.3	16.6	15.9	16.4	16.3

*Rates per acre. 2-16-8, 150 pounds; 0-20-0, 200 pounds; borax, 10 pounds; $CuSO_4$, 60 pounds; $MnSO_4$, 100 pounds.

Analysis of Variance:

Source	Wiergorski farm			Foss farm		
	DF	SS	MS	DF	SS	MS
Total	23	9.30		23	5.50	
Blocks	3	1.92	0.64	3	0.73	0.24
Treatments	5	2.31	0.46	5	1.30	0.26
Error	15	5.07	0.34	15	3.47	0.23

Table 12. The effect of phosphorus, boron, copper, and manganese on the coefficient of apparent purity of sugar beets.

Treatment*					Wiergorski farm					Foss farm				
					B1	B2	B3	B4	Mean	B1	B2	B3	B4	Mean
2-16-8	--	-	-	--	81.7	70.8	81.0	79.4	78.2	82.0	82.3	78.9	78.3	80.4
2-16-8	Cu	B	P	Mn	74.2	74.8	74.5	84.8	77.1	81.3	82.5	81.0	82.1	81.7
2-16-8	--	B	P	Mn	82.3	72.5	79.6	75.5	77.5	75.8	80.7	80.9	78.5	79.0
2-16-8	Cu	-	P	Mn	77.5	73.3	71.6	72.3	73.7	78.3	80.8	84.4	74.9	79.6
2-16-8	Cu	B	-	Mn	72.5	75.7	77.7	75.7	75.4	80.3	80.6	83.9	81.9	81.7
2-16-8	Cu	B	P	Mn	81.9	77.2	81.7	80.8	80.4	83.7	81.0	82.0	80.7	81.9

*Rates per acre. 2-16-8, 150 pounds; 0-20-0, 200 pounds; borax, 10 pounds; $CuSO_4$, 60 pounds; $MnSO_4$, 100 pounds.

Analysis of Variance.

Source	Wiergorski farm			Foss farm		
	DF	SS	MS	DF	SS	MS
Total	23	370.86		23	124.67	
Blocks	3	74.39	24.80	3	21.81	7.27
Treatments	5	107.96	21.59	5	30.82	6.16
Error	15	188.51	12.58	15	72.04	4.80

Table 13. The effect of phosphorus, boron, copper, and manganese on the per cent of plants showing boron deficiency symptoms at the Wiergorski farm.

Treatment*					B1	B2	B3	B4	Mean
2-16-8	--	-	-	--	93.6	95.7	92.7	93.1	93.8
2-16-8	Cu	B	P	Mn	30.1	20.5	20.1	24.0	23.7
2-16-8	--	B	P	Mn	19.4	5.9	29.0	16.4	17.7
2-16-8	Cu	-	P	Mn	93.4	97.7	99.4	95.3	96.5
2-16-8	Cu	B	-	Mn	18.9	22.7	15.6	2.9	15.0
2-16-8	Cu	B	P	--	28.9	14.6	29.8	11.5	21.2

*Rates per acre. 2-16-8, 150 pounds; 0-20-0, 200 pounds; borax, 10 pounds; $CuSO_4$, 60 pounds; $MnSO_4$, 100 pounds.

Analysis of Variance.

Source	DF	SS	MS
Total	23	31,620.75	
Blocks	3	224.22	74.74
Treatments	5	30,766.59	6,153.32**
Error	15	629.94	42.00
Difference required for significance			9.8

**Significant at the 1% level.

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