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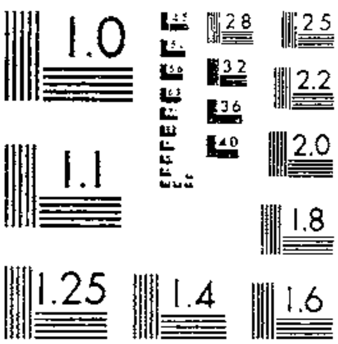

MICROCOPY RESOLUTION TEST CHART
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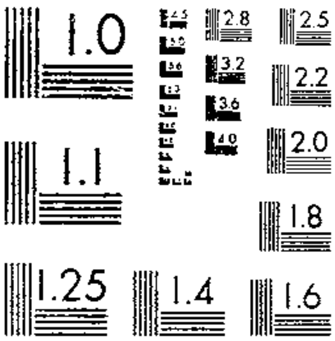

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FACTORS AFFECTING THE DEVELOPMENT OF LOOSE SMUT IN BARLEY AND ITS CONTROL BY DUST FUNGICIDES

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CONTENTS

INTRODUCTION

In the past loose smut in barley, caused by *Ustilago nuda* (Jens.) Kell. and Sw., generally speaking, has been considered amenable to control only by the hot-water treatment. In some barley varieties it has been controlled, or the percentage of infection greatly reduced, at times by the use of formaldehyde or various organic mercury solutions. In 1914, Johnson (*5*)[1] reported that a 0.3 per cent solution of 40 per cent formaldehyde (1:320) had reduced loose smut in barley to a slight trace.[2] In 1918 Humphrey and Potter (*4*) intimated that barley loose smut could be controlled or its occurrence reduced by the use of formaldehyde. Tisdale et al. (*18*) reported in 1923 that formaldehyde was as effective as hot water in the control of loose smut in six varieties of winter barley. In 1925 Tisdale et al. (*19*) reported that satisfactory control of loose smut in Wisconsin Winter, Orel, and Tennessee Winter barleys had followed the use of organic mercury solutions. Rodenhiser and Stakman (*14*) reported in 1925 that they had reduced loose smut of barley from 7 per cent to a trace by the use of organic mercury solutions at 45° C. In 1926 Conners (*1*) reported that organic mercury solutions at ordinary temperatures failed to control loose smut in Junior (hull-less) barley and only partly controlled it at 45° C., but that the modified hot-water treatment eliminated it. Kirby (*6, p. 50–53*) stated in 1927 that soaking the seed in formaldehyde or organic mercury solutions controlled loose smut in 6-row

[1] Italic numbers in parentheses refer to Literature Cited, p. 18.
[2] This was in Oderbrucker barley Wisconsin Pedigree No. 9. The controls contained 5 to 6 per cent of loose smut.

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winter barley and reduced its occurrence in certain 6-row spring varieties.[2]

In 1929, Howitt and Stone[3] reduced the percentage of loose smut in O. A. C. No. 21 barley from 10 per cent to 4, 2, and 1 per cent with solutions of formaldehyde, Semesan, and Uspulun, respectively.

These few citations indicate that loose smut of barley generally has been found more difficult to control than any other cereal smut except loose smut of wheat. Dust fungicides have not been considered effective for the control of this disease and up to the present time seldom have been used for this purpose.

In the fall of 1926 field experiments were started at the Arlington Experiment Farm, Rosslyn, Va., to test the efficacy of certain fungicidal dusts in the control of covered smut and stripe disease in Tennessee Winter barley. It was observed, during the first year of these experiments, that these dusts also reduced considerably the incidence of loose smut, which occurred to a slight degree in this variety. Therefore, data were taken on the control of this disease in this variety of barley, and further seed-treatment experiments with this and other varieties were later conducted in order to investigate the possibilities of controlling loose smut, as well as other diseases of barley, by means of dust fungicides.

METHODS AND MATERIALS

The general procedure followed by the writer in seed-treatment experiments with barley has been described in a previous paper (*9*). The dusts were usually applied at the rate of 3 or 4 ounces per bushel, and the seed was thoroughly mixed with the dusts until every kernel was completely coated. Then the seed was shaken for a moment in a fine sieve to remove any excess dust. It was sown in rod rows usually replicated a number of times for each treatment. Smut data were secured by counting all the heads of loose smut as well as the total heads in every row in order to determine the percentage of infection.

Twenty-seven dusts and two liquid disinfectants were used[4] in the course of these experiments. The names of the dust fungicides used and of the manufacturers are listed below.

Abavit B, Chemische Fabrik Ludwig Meyer, Mainz, Germany.

Tutan, S. F. A. No. 225 and No. 225–V, Saccharin-Fabrik Aktiengesellschaft, Magdeburg, Germany.

Höchst (also called "Trockenbeize Tillantin"), J. G. Farbenindustrie Aktiengesellschaft, Höchst a. M., Germany.

Vitrioline, Usines Schloesing Frères et Cie., Marseille, France.

Mercury C and Sterocide, Roessler & Hasslacher Chemical Co., Perth Amboy, N. J.

Corona 80–B and Corona Oat Dust, Corona Chemical Division of the Pittsburgh Plate Glass Co., Milwaukee, Wis.

Bayer Dust, the Bayer Co., New York.

Wa Wa Dust, the Chicago Process Co., Chicago, Ill.[5]

Smuttox, the Stadler Products Co., Cleveland, Ohio.

Sanoseed Grain Dust, Ansbacher Siegle Corporation, New York.

Acco Dust No. 7, American Cyanamid Co., New York.

[3] Unpublished data.

[4] The dusts used in these experiments were the only ones submitted to the author for experimental purposes. Their use in these experiments does not imply that any other dusts on the market at that time might not have proved efficacious under similar circumstances. The names of the manufacturers are furnished merely as information, and mention of them does not imply any recommendation of the firms or their products.

[5] Now located at Newark, N. J.

Semesan, Semesan Jr., Dupont Nos. 12, 35, 45, 53, and 64, E. I. du Pont de Nemours & Co., Wilmington, Del.
Ceresan, Dubay P. M. A., and Dubay 655 and 665, the Bayer Semesan Co., New York.
Wienert's Compound, F. Wienert, Lock Haven, Pa.

The liquid fungicides used were Germisan (made by the manufacturers of Tutan) and ordinary formaldehyde solution.

The following varieties of barley were used:

Tennessee Winter 52, C. I.[6] No. 3543.
Wisconsin Winter, C. I. No. 2159.
Wisconsin Pedigree 6, C. I. No. 1146.
Wisconsin Pedigree 5, C. I. No. 4666.
Minnesota Velvet, C. I. No. 4252.

Three lots of unknown varieties were secured from different farms in Wisconsin.

EXPERIMENTS IN 1926–27

During the 1926–27 season, in one series of six treatments replicated 48 times and with 2.5 per cent of loose smut in the controls, Wa Wa Dust and Abavit B reduced the disease to 0.01 and 0.02 per cent, respectively, while the other four dusts reduced it to less than 0.5 per cent. (Table 1.)

TABLE 1.—*Loose smut in Tennessee Winter barley grown from untreated seed and from seed treated with dust fungicides and sown in rod rows, 1926–27*

[Series 1, 48 replications, sown Oct. 12, in soil 45 per cent saturated; series 2, 24 replications, sown Oct. 16, in soil 65 per cent saturated]

Seed-treatment compound		Heads of loose smut in—			
No.	Name	Series 1		Series 2	
		Number	*Per cent*	*Number*	*Per cent*
	Control	565	2.5	243	1.01
1	Abavit-B	5	.02	0	0
2	S. F. A. No. 225-V	29	.10	0	0
3	Bayer Dust	62	.20	8	.03
4	Semesan	15	.05	0	0
5	Dupont No. 12	10	.04	0	0
6	Wa Wa Dust	4	.01	0	0

In another series of six treatments, replicated 24 times in rod rows, in which the controls showed 1 per cent loose smut (Table 1), five of the dusts eliminated the disease, while the other dust reduced it to 0.03 per cent. These results were not considered very significant on account of the low percentages of loose smut appearing in the controls.

EXPERIMENTS IN 1927–28

During the 1927–28 season 14 dusts were used in seed-treatment experiments for the control of loose and covered smuts and stripe disease in Tennessee Winter barley. Two parallel series were sown. Series 1 was sown on September 21 in relatively dry soil and series 2 on October 7 in relatively wet soil. The mean soil temperature

[6] Accession number of the Division of Cereal Crops and Diseases.

from sowing to emergence in both series was about 16° C. Very little loose smut developed in the controls in either series. (Table 2.)

TABLE 2.—*Effect of seed treatment with dust fungicides on the incidence of loose smut in Tennessee Winter barley grown in field plots, 1927–28*

[Series 1 sown Sept. 21 and grown to emergence in relatively dry soil; series 2 sown Oct. 7 and grown to emergence in relatively wet soil]

Seed-treatment compound		Heads of loose smut in—			
No.	Name	Series 1		Series 2	
		Number	*Per cent*	*Number*	*Per cent*
	Control	101	0.73	41	0.35
1	Abavit B	8	.06	0	0
2	S. F. A. No. 225	11	.08	7	.05
3	S. F. A. No. 225-V	58	.41	10	.07
4	Höchst	9	.06	3	.02
5	Tutan	59	.39	5	.04
6	Vitrioline	90	.61	15	.12
7	Mercury "C"	25	.17	8	.06
	Control	100	.68	45	[illegible]
8	Wa Wa Dust	3	.02	0	[illegible]
9	Semesan	32	.21	3	.02
10	Semesan Jr.	45	.30	1	.01
11	Dupont 35	70	.48	1	.01
12	Dupont 45	38	.26	9	.07
13	Dupont 53	60	.40	16	.13
14	Dupont 64	37	.26	10	.08

In series 1 with an average of 0.7 per cent loose smut in the controls, Abavit B, Höchst, and Wa Wa Dust reduced it the most, while in series 2 with an average of only 0.36 per cent loose smut in the controls, Abavit B and Wa Wa Dust eliminated it. These results, like those of the previous season, were not considered very significant, because of the light infection in the controls.

EXPERIMENTS IN 1928–29

During the 1928–29 season Tennessee Winter and Wisconsin Winter barleys were used in experiments on the control of barley smuts. The seed was treated with the different fungicides and, along with untreated controls, was sown in replicated rod rows in three series. Series 1, containing 20 replications, was sown September 29. This yielded no data because of total winterkilling. Series 2, containing four replications, and series 3, containing eight replications, were sown October 5 and October 18, respectively. The soil temperature and rainfall records for the periods of emergence in these two series are shown in Table 3, and the infection data taken May 6, 1929, are shown in Table 4.

TABLE 3.—*Soil temperature and rainfall records from dates of sowing seed to dates seedlings emerged, in experiments on the control of loose smut in Tennessee Winter and Wisconsin Winter barleys sown in rod rows, 1928–29*

[Series 1, 20 replications, sown Sept. 29 (winterkilled); series 2, 4 replications, sown Oct. 5, in soil 41 per cent saturated; series 3, 8 replications, sown Oct. 18, in soil 19 per cent saturated at sowing and 25 per cent two days later]

Days after sowing	Series 2				Series 3			
	Soil temperature			Rainfall	Soil temperature			Rainfall
	Maximum	Minimum	Mean		Maximum	Minimum	Mean	
	° C.	° C.	° C.	Inch	° C.	° C.	° C.	Inch
1	23	13	16.8	0	24	17	18.7	0.13
2	21	9	14.3	0.11	18	8	13.5	
3	21	8	13.7	0	20	5	11.0	
4	24	12	17.0	0	20	6	12.4	
5	23	12	16.5	0	19	13	15.2	
6	23	9	15.3	0	17	6	10.8	.11
7					15	3	8.1	
8					15	2	7.0	
9					11	0	5.2	
10					15	5	9.5	
Average or total	22.5	10.5	[1] 16.1	.11	17.4	6.5	11.1	.24

[1] Not the average of figures above, but of 2-hourly temperatures for whole period.

TABLE 4.—*Loose smut in Tennessee Winter and Wisconsin Winter barleys grown from untreated seed and from seed treated with different fungicides and sown in rod rows, 1928–29*

[Series 1, 20 replications, sown Sept. 29 (winterkilled); series 2, 4 replications, sown Oct. 5; series 3, 8 replications, sown Oct. 18]

Seed-treatment compound		Heads of loose smut in—							
		Tennessee Winter				Wisconsin Winter			
No.	Name	Series 2		Series 3		Series 2		Series 3	
		Number	Per cent	Number	Per cent	Number	Per cent	Number	Per cent
	Control	38	2.5	200	4.5	55	4.6	194	4.7
1	Ceresan	0	0	38	.9	5	.3	61	1.4
2	Dubay P. M. A.	0	0	19	.5	0	0	23	.5
3	Höchst	0	0	32	.7	1	.1	88	1.8
4	Abavit B	0	0	72	1.8	4	.3	154	3.6
5	Formaldehyde [1]	1	.2	0	0	4	.3	29	.7

[1] Treatment: Water 15 minutes, drained and covered 4 hours, 1:320 formaldehyde solution 20 minutes, drained and covered 3 hours, dried overnight.

In series 2, in which the soil was 41 per cent saturated at the time of sowing, control of loose smut in both barley varieties was better than in series 3, in which the soil was 19 per cent saturated at the time of sowing and was relatively dry during the entire period of emergence.

In the spring of 1929, seven dusts and one liquid fungicide were used in limited field experiments for the control of loose smut in barley grown from the same lot of Wisconsin Pedigree No. 5 seed used in a greenhouse experiment described later. (Table 7.) The seed was dusted at the rate of 4 ounces per bushel and sown in two series. Series 1 was sown March 13 in soil of low fertility, and the plants emerged March 24. Series 2 was sown April 6 in rich soil, and emergence took place April 14. The soil temperature and rainfall records for both series are shown in Table 5.

TABLE 5.—*Soil temperature and rainfall records from dates of sowing seed to dates seedlings emerged, in field experiments on the control of loose smut in Wisconsin Pedigree No. 5 barley, 1929*

[Series 1, sown in poor soil Mar. 13, emerged Mar. 24; series 2, sown in rich soil Apr. 6, emerged Apr. 14]

Days after sowing	Series 1				Series 2			
	Soil temperature			Rainfall	Soil temperature			Rainfall
	Maximum	Minimum	Mean		Maximum	Minimum	Mean	
	° C.	° C.	° C.	Inch	° C.	° C.	° C.	Inch
1	12	11	11.4	0.13	25	19	22.2	
2	15	11	13.0		28	14	20.4	
3	15	11	12.6	.02	27	15	20.8	
4	14	8	11.8	.05	27	17	20.8	
5	12	4	7.7		16	8	13.5	0.79
6	16	2	7.3		7	5	6.4	.03
7	14	3	7.0		22	5	12.0	.39
8	16	5	10.1		20	6	12.5	
9	19	4	10.6					
10	19	11	14.7	.09				
11	18	14	15.7	.15				
Average	15.4	7.6	11.1		21.5	11.1	16.1	

The soil in series 1 was 40 per cent saturated at the time of sowing, and 0.44 of an inch of rain fell before the plants emerged. The average soil temperature during this period was 11.1° C. Therefore, the seed germinated and the seedlings grew to emergence in a relatively cold dry soil. The smut data, which were taken June 9, are shown in Table 6.

TABLE 6.—*Loose smut in Wisconsin Pedigree No. 5 barley grown from untreated seed and from seed treated with different fungicides and sown in rod rows, 1929*

[Series 1, four replications in poor soil, sown Mar. 13; series 2, two replications in rich soil, sown Apr. 6]

Seed-treatment compound		Heads of loose smut in—			
No.	Name	Series 1		Series 2	
		Number	Per cent	Number	Per cent
	First control	21	3.0	9	1.8
1	Ceresan	0	0	0	0
2	Dubay P. M. A	1	.2	0	0
3	Höchst	0	0	0	0
4	Abavit B	0	0	0	0
	Second control	18	2.6	8	1.6
5	Mercury "C"	0	0	0	0
6	Corona 80-B	3	.4	0	0
7	Smuttox	2	.3	0	0
8	Germisan [1]	0	0	0	0

[1] 0.25 per cent solution for 1 hour.

Four of the dusts and the one liquid fungicide eliminated loose smut, while the rest of the dusts greatly reduced its occurrence in comparison with the controls from untreated seed, although the latter averaged only 2.8 per cent smut.

The soil in series 2 was about 75 per cent saturated at the time of sowing, and from sowing to emergence the rainfall amounted to about an inch. The mean soil temperature during this period was 16.1° C. In this series, therefore, the soil was warmer and much wetter during the period of emergence than the soil in series 1. No smut appeared in the rows from treated seed (Table 6), while the smut in the control rows averaged only 1.7 per cent. Evidently soil conditions in both series were highly unfavorable for loose-smut development, because in a subsequent greenhouse experiment 38.7 per cent of the plants from this same lot of seed were infected with loose smut. (Table 7.)

TABLE 7.—*Control of loose and covered smuts in Wisconsin Pedigree No. 5 barley grown from seed dusted with Ceresan and sown in the greenhouse January 5, 1929, along with untreated seed*

[Plants emerged Jan. 11, the final data being taken Apr. 6, 1929]

Row No.	Treated or untreated	Total plants	Total heads	Loose smut				Covered smut			
				Plants infected		Heads infected		Plants infected		Heads infected	
				Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
1	Untreated	17	56	6	35.3	23	41.1	6	35.3	13	23.2
2-6	Treated	93	221	0	0	0	0	0	0	0	0
7	Untreated	17	37	6	35.3	10	27.0	9	52.9	17	45.9
8-12	Treated	91	227	0	0	0	0	0	0	0	0
13	Untreated	20	34	6	30.0	6	17.6	13	65.0	19	55.9
14-18	Treated	93	223	0	0	0	0	0	0	0	0
19	Untreated	17	41	10	58.8	21	51.2	5	29.4	12	29.3
20-24	Treated	95	225	0	0	0	0	0	0	0	0
25	Untreated	20	41	6	30.0	16	39.0	8	40.0	8	19.5
26-30	Treated	95	234	0	0	0	0	0	0	0	0
31	Untreated	20	40	9	45.0	15	37.5	7	35.0	13	32.5
32-36	Treated	88	200	0	0	0	0	0	0	0	0
Totals:											
Untreated seed		111	249	43	38.7	91	36.5	48	43.2	82	33
Treated seed		555	1,330	0	0	0	0	0	0	0	0

During the winter of 1928–29 a seed-treatment experiment of rather limited scope was conducted in the greenhouse on the control of loose smut in heavily infected Oderbrucker (Wisconsin Pedigree No. 5) barley by the use of ethyl mercury chloride, a then relatively new dust which is now marketed under the trade name of Ceresan. Previously it had been found effective in the control of stripe disease in barley (*10*) and of bunt in wheat (*8*). Tisdale and Cannon (*17*) also had reported satisfactory results from its use in the control of loose smut in Tennessee Winter barley.

The greenhouse bench used was 40 feet long, 3½ feet wide, and 8 inches deep and was filled with rather rich compost soil. The seed was treated at the rate of 4 ounces of dust per bushel. It was sown 1½ inches deep in rows 6 inches apart at the rate of 20 seeds per row, every sixth row being an untreated control. The seed was treated and sown January 5, and the seedlings emerged January 11. The temperature during this time was between 20° and 25° C., and the soil was kept moderately moist. In order to hasten shooting and heading of the plants a 24-hour growing day was provided by the use of electric lights, beginning January 25. On April 6, when all the culms were fully headed, the plants were pulled carefully and plant and head counts were made. These results are shown in detail and also summarized in Table 7. Both the loose and covered smuts were completely eliminated by Ceresan, while in the controls 38.7 and 43.2 per cent of the plants and 36.5 and 33 per cent of the heads were infected with loose and covered smuts, respectively.

EXPERIMENTS IN 1929-30

The following winter an experiment similar to the one described above but on a smaller scale was carried out with seed of two other varieties known to be infected with loose smut. The resultant data are shown in Table 8.

TABLE 8.—*Loose smut in two varieties of barley grown from untreated seed and from seed treated with Ceresan and sown in the greenhouse November 4, 1929*

[Final data taken Feb. 20, 1930]

Variety	Untreated seed			Treated seed		
	Total heads	Smutted heads		Total heads	Smutted heads	
		Number	*Per cent*		*Number*	*Per cent*
Wisconsin Pedigree No. 6	60	19	31.7	197	1	0.5
Unknown variety	50	3	6.0	204	3	1.5

In one variety, Wisconsin Pedigree No. 6, loose smut was reduced to 0.05 per cent, as compared with 31.7 per cent in the controls. In the other variety (name unknown) loose smut was reduced to 1.5 per cent, while 6 per cent occurred in the controls.

While these greenhouse results with two varieties were very gratifying, it must be borne in mind that, although the conditions for smut development must have been favorable, judging by the high percentage in the controls, the conditions for the maximum efficiency of the dust fungicide used also may have prevailed to a greater degree than usually occurs in the field.

In the spring of 1930 six lots of barley seed were used in seed-treatment experiments on the control of stripe disease and loose smut. Three of these seed lots, Wisconsin Pedigree No. 5 and No. 6 and an unnamed variety from Oconomowoc, Wis., had been used in previously described experiments. (Tables 7 and 8.) The three other seed lots were obtained from different localities in Wisconsin and were known to be infected with stripe disease and to some extent with loose smut.

Quantities of seed of all six varieties or lots were treated with different standard or experimental fungicides and sown in paired rod rows March 20, 1930. The soil was 40 per cent saturated both at the time of sowing and at the time when the seedlings emerged. During this period the rainfall amounted to an inch, and the mean soil temperature was 7.5° C. Loose-smut data, taken June 4, 1930, and shown in Table 9, are not very significant on account of the light infection in the controls.

TABLE 9.—*Loose smut in six varieties of spring barley grown from untreated seed and from seed treated with different fungicides and sown in paired rod rows, March 20, 1930*

Seed-treatment compound		Heads of loose smut in—											
No.	Name	Wisconsin Pedigree No. 5		Wisconsin Pedigree No. 6		Minnesota Velvet		Farmers' samples					
								No. 1		No. 2		No. 3	
		Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
	First control	0	0	3	0.5	4	0.7	19	2.4	2	0.3	0	0
1	Ceresan	0	0	0	0	3	.5	18	2.3	0	0	1	.1
2	Dubay 655	0	0	0	0	1	.2	7	.9	0	0	0	0
3	Dubay 665	0	0	0	0	2	.3	18	2.3	1	.1	0	0
4	Abavit B	0	0	0	0	4	.7	16	2.0	5	.8	2	.2
	Second control	1	.1	2	.3	3	.4	20	2.5	1	.2	2	.2
5	Höchst	0	0	2	.3	2	.3	17	2.1	1	.2	1	.1
6	Wa Wa Dust	0	0	1	.2	2	.3	11	1.4	1	.2	2	.2
7	Corona Oat Dust	0	0	1	.2	1	.2	20	2.5	0	0	2	.2
8	Sterocide	0	0	1	.2	0	0	23	2.9	0	0	2	.2
	Third control	0	0	0	0	0	0	22	2.9	0	0	3	.4
9	Sanoseed Grain Dust	0	0	2	.3	0	0	14	1.9	0	0	0	0
10	Acco Dust No. 7	0	0	2	.3	0	0	18	2.4	0	0	0	0
11	Wienert's Compound	0	0	1	.2	1	.2	21	2.8	0	0	2	.2
12	Germisan [1]	0	0	0	0	0	0	19	2.7	1	.2	1	.1

[1] 0.25 per cent solution, one hour.

They seem to indicate, however, that none of the treatments used was wholly satisfactory, especially in the variety which showed the most infection. Here again, in Wisconsin Pedigree No. 5, it is interesting to note the almost complete absence of loose smut in the controls, as compared with 36.5 per cent loose smut in the controls from the same seed lot grown in the greenhouse. (Table 7.) Evidently conditions in the field were very unfavorable for loose-smut development, as compared with those in the greenhouse.

During the crop seasons of 1928–29 and 1929–30 loose-smut data were taken on 17 varieties of barley grown by J. W. Taylor in 1/40-acre plots at the Arlington Experiment Farm. The seed of 13 of these varieties had been treated with Ceresan as a general disease preventive. Seed of 4 varieties was sown in triplicate plots, the seed having been treated first with Ceresan or Semesan or left untreated.

All the heads of loose smut in each plot were counted and these data are shown in Table 10. In Tennessee Winter No. 52 both treatments eliminated loose smut the first year, while the second year Semesan allowed 25 smutted heads to appear in this variety, or 2.6 per cent, as much as appeared in the control plots from untreated seed. In Wisconsin Winter the treatments reduced the amount of loose smut to an average 3.7 and 6.6 per cent of that appearing in the control plots the first and second years, respectively. In Orel the amount of loose smut allowed by the treatments the first and second years was 56.5 and 51.5 per cent, respectively, of that appearing in the control plots. In Esaw the first year the plots from treated seed contained an average of 87 per cent as much smut as appeared in the control plots while the corresponding figure for the second year was 80 per cent.

TABLE 10.—*Loose smut in 17 varieties of winter barley grown from seed untreated or treated with Semesan or Ceresan and sown in 1/40-acre plots, 1928–29 and 1929–30*

Plot No.	Variety		Seed treatment	Total heads loose smut in—	
	Name	C. I. No.		1928–29	1929–30
1	Wisconsin Winter	2159	Untreated	3,120	2,100
2	do	2159	Semesan	130	113
3	do	2159	Ceresan	100	162
4	Tennessee Winter	257	do	24	29
5	Tenkow	646	do	40	40
6	Scottish Pearl	277	do	140	80
7	Pidor	901	do	11	21
8	Wisconsin Winter	2159	do	64	120
9	Oral	351	Untreated	62	100
10	do	351	Semesan	30	50
11	do	351	Ceresan	40	53
12	Han River	2163	do	0	11
13	Wisconsin Winter	2167	do	20	75
14	do	2159	do	58	105
15	Tennessee Winter No. 52	3543	Untreated	495	960
16	do	3543	Semesan	0	25
17	do	3543	Ceresan	0	0
18	Alaska	4100	do	0	12
19	Tennessee Winter	3546	do	0	6
20	do	3545	do	63	60
21	Wisconsin Winter	2159	do	166	76
22	Tennessee Winter	3534	do	5	5
23	Esaw		Untreated	2,790	702
24	do		Semesan	2,590	606
25	do		Ceresan	2,280	520
26	Wisconsin Winter	2159	do	150	43
27	Beardless No. 5	3384	do	315	
28	Beardless No. 6	2746	do	450	66
29	Wisconsin Winter	2159	do	140	65
30	Nakano Wase	754	do	60	20

Since untreated seed of the other 13 varieties was not sown, it is not known to what extent, if any, loose smut was controlled in these. The data show, however, that it was not completely eliminated in any of them, although its occurrence may have been reduced considerably. It seems that some other form of treatment, presumably a liquid, would have to be used to secure complete control of loose smut in most of these varieties.

EFFECT OF ENVIRONMENTAL CONDITIONS ON THE DEVELOPMENT AND CONTROL OF LOOSE SMUT

Much has been published on the effect of soil temperature, moisture, reaction and type, and other environmental factors during the period of germination and early growth on the development of a number of seed-borne cereal diseases. The rather voluminous literature on this subject has been admirably reviewed by Reed and Faris (*13*). However, the relation of environment to the development of loose smut in barley seems to have received relatively little study, as not much on this subject appears in the literature. Seiffert (*15*) found that shallow-sown seed produced less infection than seed deeply sown. This same result was observed in experiments at the Arlington Experiment Farm by Taylor and Zehner (*16*). Lind (*11*) reports that the addition of Chile saltpeter, superphosphate, and potash to the soil, alone or in various combinations, slightly increased the percentage of barley loose smut in six out of seven plots. Kirby (6) intimates that infection is favored by soil temperatures higher than those most favorable for the best growth of the barley seedling.

While the main purpose of the experiments described in the preceding pages was to test the relative efficiency of different fungicides in smut control, incidental observations were made in an attempt to correlate the relative severity of loose-smut infection with variations in soil moisture and soil temperature. In Table 1, for example, the soil in series 1 was about 45 per cent saturated at the time of sowing, while in series 2 it was about 65 per cent saturated. The percentage of loose smut in series 1 was twice as great as that in series 2, while control of loose smut was better in series 2. In addition to the higher soil moisture, however, a slightly lower average soil temperature in series 2 may have played some part in this difference.

The same correlation between soil moisture and percentage of loose smut seems to obtain in Table 2. When series 1 was sown the soil was 13 per cent saturated, and when series 2 was sown it was 65 per cent saturated. Here, again, more loose smut developed in the drier soil, and better control was secured in the wetter soil.

Again, in Table 4 it will be observed that in Tennessee Winter barley 2.5 per cent loose smut appeared in the controls of series 2, as compared with 4.5 per cent in the drier soil of series 3, and in both varieties the control of loose smut was better in the wetter soil of series 2.

Similar differences are evident in Table 6. In series 1, in which the soil was 40 per cent saturated when the seed was sown, more smut appeared than in series 2, in which the soil was 75 per cent saturated at the time of sowing. Control again was better in the wetter soil, although here again temperature and fertility relations may have played some part.

The significance of these results, like those relating to control of loose smut by the fungicides used, is greatly decreased by the low percentages of infection in the controls, also by the many unknown factors which enter into field experiments of this kind. To supplement these rather fragmentary field data on the relation of certain environmental factors to the development of loose smut in barley and its control, a number of experiments were conducted in the greenhouse under more or less controlled conditions. In the first of these Wisconsin Pedigree No. 6 barley was grown in metal cans 8 inches in diameter and 12 inches deep, using four lots of soil at 35, 55, 75, and 95 per cent of saturation, respectively. The soil temperature varied from 12° to 18° C. After all the plants had fully emerged they were transferred to the greenhouse bench, where they were grown until final data on loose smut were taken. These data are shown in Table 11. They indicate that, at least in this variety, a high degree of soil moisture from sowing to emergence somewhat inhibits the development of loose smut.

TABLE 11.—*Relation between percentage of soil saturation from planting to emergence and subsequent development of loose smut in Wisconsin Pedigree No. 6 barley*

Soil saturation	Plants			Heads		
	Total	Infected with loose smut		Total	Infected with loose smut	
		Number	*Per cent*		*Number*	*Per cent*
35 per cent	356	63	17.7	474	77	16.2
55 per cent	325	51	15.7	346	54	15.6
75 per cent	311	37	11.9	327	37	11.3
95 per cent	130	4	2.9	159	5	3.1

During the 1929–30 season treated and untreated seed of Wisconsin Pedigree No. 5 barley was used in a greenhouse experiment designed to show the effect of soil moisture on the development and control of loose smut. A greenhouse bench 42 inches wide was divided into three sections each 16 feet long. The soil in these sections, 1, 2, and 3, was adjusted to 37, 64, and 73 per cent, respectively, of its water-holding capacity. The seed was treated with Ceresan and sown 1½ inches deep in rows 6 inches apart, and every eighth row was sown with untreated seed of the same seed lot. Sections 1 and 2 were covered with canvas until the seedlings emerged, while section 3 was watered daily so that at times the water content of the soil undoubtedly was much over 73 per cent of its water-holding capacity. The average temperature in the greenhouse was 15° C. After the seedlings had emerged a test showed that the soil in sections 1, 2, and 3 contained 25, 57, and 70 per cent, respectively, of its water-holding capacity.

When the plants were fully headed they were carefully pulled and counts were made to determine the percentage of disease in each section. Since considerable covered smut and stripe disease developed, data were taken also on these diseases. These data are shown in Table 12.

TABLE 12.—*Relation of soil moisture to development and control of stripe disease, loose smut, and covered smut in Wisconsin Pedigree No. 5 barley grown from untreated seed and seed treated with Ceresan and sown in the greenhouse under three conditions of soil moisture, 1928–29*

Soil saturation	Treated or untreated seed	Total number of plants	Plants infected with—					
			Stripe disease		Loose smut		Covered smut	
			Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*
70 to 73 per cent	Untreated	64	6	9.4	8	12.5	2	3.1
	Treated	181	0	0	1	.6	0	0
57 to 64 per cent	Untreated	50	4	8.0	6	12.0	3	6.0
	Treated	136	0	0	0	0	0	0
25 to 37 per cent	Untreated	82	12	14.6	28	34.1	15	18.2
	Treated	199	1	.5	0	0	0	0
Total or average	Untreated	196	22	11.2	42	21.4	20	10.2
	Treated	516	1	.2	1	.2	0	0

In the controls all three diseases developed most abundantly at the lowest soil moisture. Contrary to expectations, however, the only smutted plant from treated seed was found growing in the wettest soil. However, it was in a row adjacent to a control row, and since this section had been watered freely after being sown, it is probable that an untreated infected kernel was washed from the near-by control row. On the other hand, the only stripe-diseased plant from treated seed was found in the driest soil. The results from this experiment are in agreement with those from the preceding experiment as far as soil moisture and loose-smut development are concerned.

In another experiment seed of Wisconsin Pedigree No. 5 barley was sown in 8-inch cans in each of 16 soil-temperature tanks to determine, if possible, the influence of soil temperature and soil moisture upon loose-smut development. Four soil temperatures were maintained: 10°, 15°, 20°, and 25° C. In each tank the soil in half the number of 8-inch cans was adjusted to 74.1 per cent and in the other half to 42.5 per cent of its water-holding capacity. The construction and operation of the equipment used have been previously described (7).

When the plants reached the third-leaf stage they were transplanted to a greenhouse bench, where they were allowed to grow until fully headed. When fully headed the plants were pulled and counts made of healthy and diseased plants and heads. (Tables 13 and 14.) The data presented in Table 13 indicate that the higher soil temperatures were somewhat more favorable for loose-smut infection, especially in the wetter soil. However, there was not enough reduction in the percentage of loose smut at the lowest temperature (10° C.) to explain its almost total absence in plants grown from this same lot of seed in the field at slightly lower and higher average soil temperatures. (Tables 6 and 9.)

TABLE 13.—*Loose smut in Wisconsin Pedigree No. 5 barley grown from naturally inoculated seed sown in the greenhouse, the plants being grown to the fourth-leaf stage under controlled conditions of soil temperature and soil moisture, 1929–30*

Replication No.	Mean soil temperature	Soil 74.1 per cent saturated			Soil 42.5 per cent saturated		
		Total heads	Smutted heads		Total heads	Smutted heads	
	°C.	*Number*	*Number*	*Per cent*	*Number*	*Number*	*Per cent*
1	24.7	92	43	46.7	95	38	40.0
2	25.3	81	37	45.7	80	32	40.0
3	25.2	87	33	37.9	67	16	23.9
4	24.7	93	29	31.2	84	20	23.8
Total or average	25.0	353	142	40.2	326	106	32.5
1	19.8	92	34	37.0	81	22	27.2
2	20.0	80	31	38.8	81	25	30.9
3	20.4	88	40	45.5	94	37	39.4
4	19.8	90	34	37.8	84	21	25.0
Total or average	20.0	350	139	39.7	340	105	30.9
1	16	86	28	32.6	93	28	30.1
2	15.3	68	15	22.1	80	22	27.5
3	15.1	73	25	34.2	80	22	27.5
4	15.1	92	29	31.5	90	19	21.1
Total or average	15.4	319	97	30.4	343	91	26.5
1	11.3	72	15	20.8	73	27	37.0
2	10.0	72	14	19.4	75	16	21.3
3	10.7	64	11	17.2	79	15	19.0
4	10.7	79	28	35.4	71	20	28.2
Total or average	10.7	287	68	23.7	298	78	26.2

TABLE 14.—*Stripe disease, loose smut, and covered smut in Wisconsin Pedigree No. 5 barley grown in the greenhouse from naturally inoculated seed, the plants being grown to the fourth-leaf stage under controlled conditions of soil temperature and soil moisture, 1929–30*

Replication No.	Mean soil temperature	Soil 74.1 per cent saturated			Soil 42.5 per cent saturated		
		Stripe disease	Loose smut	Covered smut	Stripe disease	Loose smut	Covered smut
	° *C.*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*	*Per cent*
1	24.7	9.1	40.3	29.9	5.3	40.0	32.0
2	25.3	6.5	40.3	26.6	7.8	35.1	27.3
3	25.2	2.5	37.0	38.3	4.5	23.9	30.0
4	24.7	1.2	32.5	49.4	6.9	21.9	31.5
Average	25	4.7	37.4	36.8	6.2	30.5	30.1
1	19.8	13.6	30.8	46.9	11.4	26.6	54.4
2	20.0	17.7	33.0	38.0	7.9	28.9	47.4
3	20.4	16.4	39.7	41.1	18.0	32.6	44.9
4	19.8	18.4	31.0	41.7	19.3	22.9	43.4
Average	20.0	16.6	33.4	42.2	14.4	27.8	47.6
1	16	18.5	28.4	38.3	12.9	24.6	36.3
2	15.3	8.4	20.8	41.6	20.9	25.5	36.0
3	15.1	15.8	29.2	28.0	21.5	22.7	28.4
4	15.1	14.9	26.4	32.2	12.9	20.4	32.2
Average	15.4	14.6	26.4	34.8	17.2	23.2	33.1
1	11.3	22.0	16.5	26.4	15.7	30.1	18.1
2	10	20.0	15.3	25.2	9.6	16.9	36.1
3	10.7	20.0	13.8	36.3	8.5	18.3	39.0
4	10.7	15.1	29.1	30.2	13.0	23.4	31.2
Average	10.7	19.3	18.7	30.1	11.7	22.2	31.1

It will be observed in Table 14 that in 12 of the 16 tanks, and at three of the four temperatures, more loose smut developed in the plants grown in the soil which was 74.1 per cent saturated than was found in the plants grown in the drier soil. These results which, according to Student's method (*12*), are significant by odds of 60 to 1, are somewhat the reverse of results obtained in previous experiments, as shown in Tables 1, 2, 4, 6, 11, and 12. In these experiments the soil temperatures invariably were relatively low during the periods of emergence, and in no case were they as uniform as that of the soil in the constant-temperature tanks. It is possible that fluctuating soil temperatures may affect loose-smut development differently than does a constant soil temperature. This remains to be determined.

Reed and Faris (*13*) refer to soil moisture, soil temperature, and soil reaction as "interdependent factors" and infer that the "optimum temperature for infection" may change with a change in the other interdependent factors. In line with this theory it will be noted that slightly more infection occurred in the drier soil at 10° C. than in the wetter soil and that at the other temperatures the reverse was true.

The true relation of soil temperature and soil moisture to loose-smut development in these experiments, however, may have been obscured to a considerable degree by the interaction of stripe disease and covered smut which developed to such an extent that data on the percentage of plants affected by these diseases as well as those affected by loose smut are shown in Table 14. Stripe disease varied in severity from 1.2 to 22 per cent, while covered smut varied from 18.1 to as high as 54.4 per cent in the different replications. To what extent these diseases inhibited the development of loose smut is a question, but undoubtedly the presence, to such a great extent, of two other competing fungi, the development of both of which also are affected by variations in soil moisture and soil temperature, masked to some extent the true response of loose smut to these environmental conditions and in a sense defeated the purpose of the experiment.

During the 1930–31 season an experiment similar to the one described above was conducted in the constant-temperature tanks (7) in the greenhouse with a lot of barley seed known to be relatively free from diseases other than loose smut. The seed used was of an unknown variety grown on a farm near Oconomowoc, Wis., and had been used in two previous experiments. (Tables 8 and 9.) The approximate soil temperatures used were 10°, 15°, 20°, and 25° C. At each temperature the soil was adjusted to four different percentages of its water-holding capacity, namely, 30, 50, 70, and 90 per cent. Two depths of planting, 1½ and 3 inches, were employed at each temperature and each moisture.

The seed was sown November 3, 1930. The lengths of time required by the differently environed seedlings to emerge are shown in Table 15. When the plants had reached the fourth-leaf stage, they were transferred to the greenhouse bench. Here they were exposed to an 18-hour day until they were fully headed, when final data were taken. These data, presented in Table 16, were disappointing because the percentages of smut which developed were too small to show any significant differences in infection due to soil moisture, soil temperature, or depth of planting the seed. In a previous greenhouse experiment in which a soil temperature of about 15° C. had been maintained (Table 8), 6 per cent of loose smut had occurred in the plants grown from this same seed lot. It had been thought possible that much higher percentages of infection might be obtained under different conditions and thus yield results of value, but this did not prove to be the case.

TABLE 15.—*Influence of soil temperature, soil moisture, and depth of planting on the number of days required for emergence in barley*

Temperature of soil	Days required for emergence of barley seedlings grown from seed sown at depths and in soil with percentage of saturation shown							
	30 per cent		50 per cent		70 per cent		90 per cent	
	1.5 inches	3 inches	1.5 inches	3 inches	1.5 inches	3 inches	1.5 inches	3 inches
10° C.	16	18	13	15	11	13	11	13
15° C.	10	12	8	9	7	8	7	8
20° C.	9	10	6	7	5	6	4	5
25° C.	8	9	5	6	5	6	3	4

TABLE 16.—*Results from an experiment designed to show the effect of soil moisture, soil temperature, and depth of planting upon loose-smut infection in barley, 1930–31*

Soil saturation	Smutted plants from seed sown 3 inches deep in soil maintained at—								Results summarized as to soil moisture		
	10° C.		15° C.		20° C.		25° C.		Total plants	Infected plants	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*		*Number*	*Per cent*
30 per cent	2	2.0	1	1.0	4	4.5	1	1.2	365	8	2.2
50 per cent	1	1.0	4	4.9	5	6.8	5	6.1	338	15	4.5
70 per cent	6	6.4	1	1.3	3	3.8	1	1.2	331	11	3.3
90 per cent	6	5.6	3	3.4	4	4.3	1	1.0	395	14	3.5
Total	15	3.7	9	2.6	16	4.9	8	2.3	1,427	48	3.4

Soil saturation	Smutted plants from seed sown 1.5 inches deep in soil maintained at								Results summarized as to soil moisture		
	10° C.		15° C.		20° C.		25° C.		Total plants	Infected plants	
	Number	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*	*Number*	*Per cent*		*Number*	*Per cent*
30 per cent	1	1.0	2	2.0	3	3.5	4	5.8	354	10	2.8
50 per cent	4	3.9	2	1.9	3	3.4	3	3.7	376	12	3.2
70 per cent	0	0	5	5.4	3	4.2	0	0	354	8	2.3
90 per cent	2	1.5	1	.8	2	1.8	1	.9	478	6	1.3
Total	7	1.6	10	2.4	11	3.1	8	2.3	1,562	36	2.3

In the experiments with Wisconsin Pedigree No. 5 barley, described above, the percentage of infected plants from one lot of naturally inoculated seed varied from a slight trace to over 40 per cent. The low percentages of infection (trace to 2.5 per cent) occurred in the field, and the high percentages (12 to 40 per cent) in the greenhouse. In the field the average temperatures during the periods of emergence ranged from 9° to 16° C., while the soil moisture varied from 40 to 75 per cent of saturation.

This range of soil temperature and moisture conditions was duplicated in experiments in the greenhouse (Tables 12, 13, and 14), yet in no case was less than 12 per cent of loose smut obtained. It seems evident that some other unknown factors inhibited the development of loose smut in the field and stimulated it in the greenhouse. The possible influence of fluctuating soil temperature in this connection has been mentioned. Faris (*2*), however, working with barley-covered smut, secured more infection at a varying temperature than at any constant temperature. He also found that the optimum temperature for infection varied with the soil reaction from 10° to 20° C. While soil reaction may exert some influence on loose-smut development, it is hardly probable that, in this case, it was responsible for the lack of infection in the field, because the soil in the greenhouse and in the field was of the same type.

It was thought that the development of loose smut might have been greatly influenced by the abnormally long growing day maintained in the greenhouse by means of electric lights. Garner et al. (*3*) found that in certain plants the length of the daily light period may determine not only the quantity of carbohydrate produced but also its form, its utilization, the acidity of the sap, and the water content of the tissues. To determine whether the length of the daily light period would influence the development of loose smut, seed of Wisconsin Pedigree No. 5 barley was sown December 5, 1930, in two sections of the greenhouse bench. One section was given a daily 18-hour light period until the plants had headed. The other section received no artificial light. To vary the experiment, half of the seed in each section was artificially smutted with spores of loose smut.

The plants exposed to a daily 18-hour light period were fully headed by March 10, at which time data were taken on the percentage of plants infected with loose and covered smuts. Similar data on the plants which had received a normal daily light period could not be taken until April 15. These data, presented in Table 17, show that the high percentage of loose smut in this variety of barley in previous greenhouse experiments could not be attributed to the abnormally long daily light period to which the plants had been exposed. Table 17 shows that slightly more loose-smut infection occurred in the plants receiving a normal daily light period than in those exposed to additional artificial illumination. This held true for the plants from both smutted and unsmutted seed.

TABLE 17.—*Effect of two different daily light periods on the percentages of loose and covered smuts in Wisconsin Pedigree No. 5 barley grown in the greenhouse (December, 1930, to April, 1931) from seed which was naturally inoculated with both smuts, and half of which was also artificially inoculated with spores of loose smut*

Length of daily light period	Seed artificially smutted or not	Total plants grown	Plants infected with— Loose smut		Covered smut	
			Number	*Per cent*	*Number*	*Per cent*
18-hour day	Not smutted	165	53	32.1	68	41.2
	Smutted	200	106	53	62	31
Normal day	Not smutted	155	62	40	60	38.7
	Smutted	160	88	55	55	34.4

It is probable that other conditions of growth in the greenhouse, different from those in the field, were responsible for the high percentages of loose smut consistently obtained in the greenhouse. Among these may be mentioned the diminished intensity of the light in the greenhouse, which, by making the plants more succulent, may have favored the growth of the smut fungus.

SUMMARY

From the field experiments and observations described it seems evident that dust fungicides are not effective in the control of loose smut in barley except in certain varieties. In those varieties, such as Wisconsin Pedigree No. 5 and Tennessee Winter No. 52, in which natural seed inoculation by the loose-smut fungus evidently takes place somewhat like that by the organisms causing covered smut or stripe disease, the more effective dust fungicides will control the disease. In varieties in which most seed inoculation by the loose-smut fungus takes place apparently like that by the fungus causing loose smut in wheat the hot-water treatment is the only one known to be effective in controlling the disease.

Very wet soil (about 90 per cent saturated) seems to inhibit somewhat the development of loose smut and favors its control by dust fungicides. Very dry soil, containing barely enough moisture to bring about germination and emergence, seems to be conducive to loose-smut development and unfavorable to its control by dust fungicides. Between these two extremes, other conditions remaining the same, variation in soil moisture does not seem to affect greatly the development of loose smut in barley or its control, the percentage of infection usually being less than in very dry soil and more than in very wet soil.

A relatively high soil temperature before emergence seems to favor loose-smut development more than does a low soil temperature. From 20 to 100 per cent more infection occurred at 25° C. than at 10° C. in Wisconsin Pedigree No. 5 barley grown from naturally inoculated seed. Other factors, however, such as the interaction of other diseases caused by seed-borne organisms, may have been largely responsible for these results.

On the whole the data relating to the effects of environmental factors on infection by the barley loose-smut fungus are somewhat fragmentary and incomplete and are presented here more as a preliminary than as a final report. More extensive experiments with a number of varieties are desirable to establish more definitely the relations of these different factors to loose-smut infection in barley. There are indications that the influence of environment is not confined to the period of germination and early growth, but may extend over a considerable part of the life of the plant.

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