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*FURTHER EXPERIMENTS ON THE CONTROL OF BARLEY SMUTS

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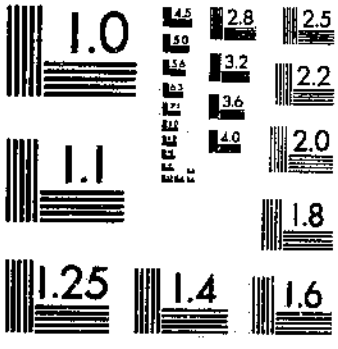

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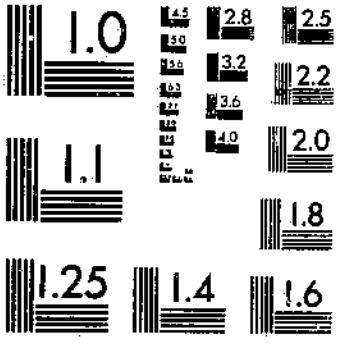

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FURTHER EXPERIMENTS ON THE CONTROL OF BARLEY SMUTS

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INTRODUCTION

In 1930 the writer (*7*)[2] presented the results of early experiments on the control of barley covered smut (*Ustilago hordei* (Pers.) Kell. and Sw.) with dust fungicides, together with a rather comprehensive review of the pertinent literature on the subject up to that time. The development since then of new fungicidal dusts, some of which were effective in controlling barley stripe (*Helminthosporium gramineum* Rabh.) (*9*) and black loose smut (*Ustilago nigra* Tapke) (*8*),[3] made it seem desirable to continue experiments on the control of covered smut with dust fungicides.

The principal difficulty encountered in work with barley covered smut lies in securing seed that will produce plants with a high percentage of smutted heads, and in growing a crop, especially during and shortly after emergence (*3*), under conditions highly conducive to infection, so as to furnish an adequate test for the fungicides used or for the varieties being studied. The failure to secure infection through seed inoculation has been mentioned by Aamodt and Johnson (*1*), Briggs (*2*), Tisdale (*16*), and others.

Blackening the seed with spores of covered smut usually does not bring about heavy infection. Furthermore, control under these conditions is not always a reliable criterion of the effectiveness of a fungicide, because in nature much of the inoculum is found under the glumes

[1] The writer gratefully acknowledges the assistance of V. F. Tapke, of the Division of Cereal Crops and Diseases, in distinguishing between the two loose smuts.

[2] Italic numbers in parentheses refer to Literature Cited, p. 10.

[3] Later investigations have shown that the barley loose smut eliminated by fungicidal dusts was not the loose smut caused by *Ustilago nuda* (Jens.) Kell. and Sw., but was caused by another species, to which Tapke (*14*) has applied the name *U. nigra*.

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and is not readily reached by surface disinfectants. A similar objection applies to the removal of the glumes before applying the smut spores, as is commonly done in resistance studies (*2, 16*), for it is well known that covered smut in hull-less varieties is more easily controlled than it is in varieties having hulls. Furthermore, removing the hulls by hand is too laborious, and the use of sulphuric acid for this purpose injures the seed (*1, 5*) and masks the effects of the fungicides. Therefore efforts were made to secure for the experiments described herein seed from barley fields containing a high percentage of heads infected with covered smut.

REVIEW OF LITERATURE

Comparatively little that is new in the treatment of barley seed for covered smut control has been reported during the past few years. Many investigators still recommend treatment with formaldehyde, copper sulphate, or hot water. Morwood (*10*), in Australia, used the dusts Abavit B and Tillantin R with good results. He states that the best dusts, according to the literature on the subject, are Abavit B, Höchst, Ceresan, and Smuttox. Only the last two are available commercially in the United States. Jones (*6*), in Egypt, obtained considerable reduction in the percentage of covered smut by dusting the seed with sulphur. Nattrass (*11*) reports similar results from Cyprus. Petit (*12*), in Tunis, obtained commercial control of covered smut by dusting the seed with cuprous chloride or diluted cupric chloride. During the past 2 years a number of investigators in the United States have, in correspondence with the writer, reported satisfactory control of barley covered smut with Ceresan and New Improved Ceresan.

MATERIALS AND METHODS

SEED USED

For experiments on the control of covered smut, Tennessee Winter barley was obtained from fields showing abundant infection with this disease. In 1932 seed was obtained from a field near Brookeville, Md., that showed 25 percent of covered smut and 5 percent of stripe. Additional inoculum was applied to the seed in the form of powdered smut spores.

In July 1933 a barley field near Poolesville, Md., was observed to contain over 30 percent of covered smut. Clouds of smut were visible at threshing time, and the seed in the bin was dark with smut spores. The barley was threshed from the shock shortly after harvesting and the seed was obtained immediately after threshing, so that it did not go through a "sweat" as it presumably does in a mow, stack, or granary. No additional inoculum was used.

In September 1934 a supply of smutty barley was obtained from a farm near Frederick, Md., about 2 months after it had been threshed in a cloud of smut. This seed was divided into three lots. Lot 1 received no additional inoculum; lot 2 was dusted with spores of covered smut at a 1 to 250 spore dosage, i. e., 1 g of spores to 250 g of seed; and lot 3 was inoculated by the evacuation method described by Haarring (*4*) and carried out as follows:

A suspension was made by shaking up 5 g of covered smut spores in 3,000 cc of a 2-percent dextrose solution. The barley, 500 g at

a time, was immersed in this suspension and subjected to 35 inches of vacuum for 20 minutes, the container being shaken occasionally to thoroughly wet the barley and also to facilitate the escape of air from beneath the glumes. This air presumably is replaced by the spore suspension, which is forced into the evacuated space beneath the glumes. The seed was then drained and dried overnight. The three lots were stored in a chamber at 25° to 28° C. and a relative humidity of 80 to 90 percent for 72 hours. After the seed was aired for a day the treatments were applied.

For experiments on the control of black loose smut (*Ustilago nigra*) (*14*), in the spring of 1934, seed of Alpha barley from a crop infected with both loose smuts was obtained from the New York Agricultural Experiment Station, Ithaca, N. Y. It was inoculated in September 1933 with spores of *U. nigra* by the evacuation method as described above, except that a lower temperature (22° C.) prevailed during the subsequent incubation.

For similar experiments of rather limited scope during the season of 1934–35, smut-free Alpha seed was inoculated with spores of *Ustilago nigra* both by the evacuation method and by applying dry spores to the seed. Both lots of seed were incubated as before, after which they were stored in the laboratory for 1 month before the treatments were applied.

FUNGICIDES USED

The following materials were used as fungicides:[3]

Ceresan, 2-percent ethyl mercuric chloride, from Bayer Semesan Co., Wilmington, Del.

New Improved Ceresan, 5-percent ethyl mercuric phosphate, from Bayer Semesan Co., Wilmington, Del.

Sanoseed Grain Dust, 5-percent ethanol mercuric chloride, from Ansbacher Siegle Corporation, New York, N. Y.

Grainaide, organic mercury, methyl aldehyde, and other materials (percentages not given) in inert material, from Farmaide Co., Lincoln, Nebr.

Smuttox, 4-percent formaldehyde in inert material, from Stadler Products Co., Cleveland, Ohio.

Ansul Dust, 6-percent formaldehyde in inert material, from Ansul Chemical Co., Marinette, Wis.

P. A. C. Dust, 6- to 8-percent formaldehyde in inert material, from E. I. du Pont de Nemours & Co , Wilmington, Del.

Corona Oat Dust, 5-percent formaldehyde in inert material, from Corona Chemical Division, Pittsburgh Plate Glass Co., Milwaukee, Wis.

S. K. 413–a, a complex phenol-mercury compound made in Germany.

Hongosan, an experimental naphthalene compound received from Mexico.

Ordinary dusting sulphur.

Formaldehyde solution.

Copper oxychloride and copper sulphate dusts also were included in one experiment.

The dust fungicides were applied to the seed by means of a mechanical device previously described (*7*), and the rates of application ranged from one-half to 4 ounces per bushel, largely according to the recommendations of the manufacturers. After treatment the seed was kept covered for about 24 hours, after which it was stored in open containers until sown.

[3] The dusts used in these experiments were the only ones submitted to the writer for experimental purposes. Their use in these experiments does not imply that other dusts on the market at that time might not have proved equally 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.

If the seed was to be sown immediately, the formaldehyde treatment consisted of a 2-hour soak in a 1:320 solution. If sowing was to be delayed, the seed was first soaked in water for 15 minutes and covered for 4 hours, then immersed in a 1:320 formaldehyde solution for 1 hour, drained and covered 1 hour, rinsed in water, and dried. The object of the preliminary soak and subsequent rinse was to prevent seed injury. All the treatments were carried out at the Arlington Experiment Farm, Rosslyn, Va.

SOWING

With one exception all sowings were done at the Arlington Experiment Farm. In the fall of 1932 the seed was sown by hand in rod rows replicated 10 times for each treatment. In the covered-smut experiments of 1933–34 the seed was sown with a Columbia hand planter set to sow slightly less than a gram per foot. One 132-foot row was devoted to each treatment. In similar experiments during 1934–35 one series was sown in rod rows in rather poor soil at Statesville, N. C., another in 5-foot rows in specially prepared beds near the greenhouse at the Arlington Farm, and a third series in the same field and same manner as in 1933–34.

The Alpha barley used for loose-smut studies was sown in the greenhouse and in outdoor beds in 1934 and only in the greenhouse in 1935.

TAKING DATA

Data on infection in the field were taken by recording separately the number of heads of covered and loose smut and the number of striped plants, if any, in each row. All the heads were counted in those rows in which more than a trace of either smut appeared.

Data on the loose smut experiments in the greenhouse and in the outdoor beds were obtained by pulling up the plants and counting total and infected plants or heads.

Germination data were obtained by sowing usually 300 seeds of each treated lot in the greenhouse and counting the emerged seedlings before the second leaf appeared.

EXPERIMENTAL DATA

RESULTS IN 1932-33

Thirteen dusts were used and all were applied at 4 ounces per bushel. The data on germination are shown in table 1. Ethyl mercuric phosphate no. 1100 severely injured the viability of the seed. Grainaide, Corona Oat Dust, and copper sulphate also caused some reduction in the percentage of emergence. Because of the complete winter-killing of the plants in the field plots, data on smut control were not obtained.

TABLE 1.—*Emergence in Tennessee Winter barley grown from seed inoculated with covered smut, treated with various dust fungicides at 4 ounces per bushel or a 1:320 formaldehyde solution, and sown in the greenhouse in October 1932*

Seed treatment		Germination	Seed treatment		Germination
No.	Fungicide		No.	Fungicide	
		Percent			*Percent*
	Average of controls	93		Average of controls	95
1	Ceresan	95	8	Grainaide	83
2	E. M. P. no. 981[1]	85	9	Copper oxychloride no. 1	96
3	E. M. P. no. 1100[1]	12	10	Copper oxychloride no. 2	94
4	Sanoseed Grain Dust	92	11	Copper sulphate no. 1	93
5	Ansul Dust	91	12	Copper sulphate no. 2	74
6	Smuttox	87	13	S. K. 413-a	92
7	Corona Oat Dust	81	14	Formaldehyde	65

[1] Ethyl mercuric phosphate, experimental forerunners of New Improved Ceresan.

RESULTS IN 1933-34

Nine dusts were used at two rates of application on each of two dates, as shown in table 2. The formaldehyde treatment included a preliminary soak and a subsequent rinse in water. A water treatment was included for comparison. The sowing in the greenhouse for germination data was made 3 days after the treatments were applied. None of the treatments caused any significant increase or decrease in the percentage of emergence.

TABLE 2.—*Emergence and covered and loose smuts and stripe in Tennessee Winter barley grown from seed untreated or treated and sown by means of a nursery drill in 132-foot rows, Sept. 27, 1933*

[Data taken May 17, 1934]

Seed treatment				Infection in plants grown from seed treated—							
				2 weeks before sowing				2 days before sowing			
				Covered smut		Loose smut	Stripe	Covered smut		Loose smut	Stripe
No.	Fungicide	Rate per bushel	Germination	Number[1]	Percent	Number[1]	Percent	Number[2]	Number[1]	Percent	Number[1]	Percent	Number[2]
		Oz.	*Percent*										
1	Untreated		84	55	2.20	33	1.32	5	50	2.00	18	0.72	2
2	Ceresan	2	88	0	.00	5	.20	0	0	.00	2	.08	0
3	do	3	86	0	.00	5	.20	0	0	.00	1	.04	0
4	New Improved Ceresan	½	85	0	.00	3	.12	0	0	.00	2	.08	0
5	do	1	83	0	.00	1	.04	0	0	.00	2	.08	0
6	Sanoseed Grain Dust	2	82	7	.28	7	.28	2	8	.32	8	.32	1
7	do	3	82	2	.08	9	.36	1	6	.24	11	.44	1
8	Grainaide	2	81	3	.12	8	.32	1	1	.04	3	.12	2
9	do	3	84	2	.08	7	.28	1	4	.28	3	.12	2
10	Smuttox	3	82	2	.08	7	.28	6	7	.28	9	.36	6
11	do	4	84	2	.08	7	.28	8	2	.08	0	.00	7
12	Untreated		81	107	4.28	23	.92	10	48	1.92	17	.68	5
13	Ansul Dust	2	81	47	1.88	25	1.00	4	53	2.12	23	.92	5
14	do	3	85	52	2.08	11	.44	5	78	3.12	16	.64	9
15	P. A. C. Dust	2	85	10	.40	7	.28	12	7	.28	5	.20	6
16	do	3	86	3	.12	2	.08	7	0	.00	10	.40	5
17	S. K. 413-a	2	82	0	.00	1	.04	0	0	.00	10	.40	3
18	do	3	82	0	.00	2	.08	0	4	.16	8	.32	0
19	Hongosan	2	85	34	1.36	28	1.12	0	38	1.52	22	.88	6
20	do	3	90	14	.56	18	.72	1	39	1.56	28	1.12	1
21	Formaldehyde	(3)	85	11	.44	1	.04	1	9	.36	6	.24	2
22	Water	(4)	88	30	1.20	4	.16	1	102	4.08	9	.36	9
23	Untreated		86	38	1.52	22	.88	15	68	2.72	22	.88	8

[1] Heads.
[2] Plants.
[3] Seed soaked in a 1 to 320 solution for 1 hour.
[4] Seed soaked in water for 2 hours.

The field sowing was done September 27, and the seedlings emerged October 2. The air temperature ranged from 12° to 27° C. and averaged 21° during that period. Precipitation totaled 0.35 inch the first 3 days and 1.2 inches on October 1. Although these conditions were not unfavorable to infection (*3*) and although the seed used had come from a badly infected crop, an average of less than 2.5 percent of the heads from untreated seed showed covered smut infection.

Ceresan and New Improved Ceresan eliminated this small percentage of covered smut, while S. K. 413–a, Sanoseed Grain Dust, Grainaide, Smuttox, P. A. C. Dust, and formaldehyde reduced it to less than 0.5 percent.

Very little loose smut appeared in the control rows, and the failure of the best treatments to completely eliminate it indicates the presence of some infection by the brown loose smut, *Ustilago nuda*. The great reduction in the percentage of loose smut resulting from some of the treatments, however, leaves little doubt that most of the infection was due to *U. nigra*. What stripe occurred was eliminated only by the same treatments that eliminated covered smut. In general, no advantage or disadvantage resulted from treating the seed 2 weeks before sowing.

The meager data on loose smut control shown in table 2 are supplemented by the data obtained from experiments with Alpha barley in the spring of 1934 and presented in table 3. The seed was treated March 6 with the same dusts used for covered smut control the previous fall, and was sown late the following day in a greenhouse bench. Germination data from this planting are shown in table 3. Another sowing was made April 2 in outdoor beds.

TABLE 3.—*Emergence and loose smuts (Ustilago nuda and U. nigra) in Alpha barley grown from seed inoculated by the evacuation method with spores of U. nigra, treated with fungicides, and sown in two series, 1934*

Seed treatment			Germination	Series 1 (sown in greenhouse Mar. 7)			Series 2 (sown in outdoor beds Apr. 2)		
No.	Fungicide	Rate per bushel		Plants grown	Plants infected with—		Plants grown	Plants infected with—	
					U. nuda	*U. nigra*		*U. nuda*	*U. nigra*
		Ounces	*Percent*	*Number*	*Percent*	*Percent*	*Number*	*Percent*	*Percent*
1	Inoculated, untreated	-------	76	179	5.0	48.0	148	5.4	30.4
2	Ceresan	3	86	209	5.3	.0	147	3.4	.0
3	New Improved Ceresan	½	85	207	5.8	.0	164	3.0	.0
4	Sanoseed Grain Dust	3	85	212	6.6	10.8	150	7.3	10.0
5	Grainaide	3	80	197	5.1	3.0	144	2.1	1.4
6	Smuttox	3	82	210	8.6	3.3	139	2.2	5.0
7	Untreated	-------	83	196	7.7	48.5	123	5.7	33.3
8	Ansul Dust	3	80	190	4.2	53.2	148	4.8	33.6
9	P. A. C. Dust	3	82	193	6.7	1.6	133	4.5	2.3
10	S. K. 413–a	3	88	216	7.4	8.8	158	7.0	7.6
11	Hongosan	3	84	203	6.4	39.4	163	4.3	29.4
12	Formaldehyde (liquid)	(1)	72	174	4.6	.0	141	3.5	.0
14	Uninoculated, untreated	-------	86	180	5.0	6.0	120	5.0	4.0

[1] Seed soaked in a 1:320 solution for 1 hour.

Infection data were taken by separating the pulled plants into three lots: (1) Healthy, (2) infected with black loose smut (*Ustilago nigra*), and (3) infected with brown loose smut (*U. nuda*). The separation between the two loose smuts was based upon general head characters, spore color, and numerous observations of germinating spores (*14*).

Ceresan, New Improved Ceresan, and formaldehyde eliminated all black loose smut, while Grainaide, Smuttox, and P. A. C. Dust reduced its occurrence to 5 percent or less. Sanoseed Grain Dust and S. K. 413–a proved less effective, while Ansul Dust and Hongosan proved wholly ineffective. The controls averaged 48.3 and 31.9 percent in the first (indoor) and second (outdoor) series, respectively. The influence of temperature on infection is at once apparent. The indoor temperature during the period of emergence ranged from 15° to 25° C., while that outdoors ranged from 5° to 28° with a balanced average of 13°. The optimum temperature for the development of the black loose smut has been found to be from 15° to 20° C.[4]

RESULTS IN 1934–35

During the 1934–35 season, four fungicidal dusts were used in the experiments on covered smut control, along with a formaldehyde solution for comparison. New Improved Ceresan was applied at one-half ounce and the other dusts at 3 ounces per bushel. The formaldehyde treatment again included a preliminary soak and a subsequent rinse in water. The three lots of seed, inoculated as previously described, were treated September 28 and sown in series 1 and 2 on October 2 and in series 3 on October 12. Data on the effect of the treatments on germination were secured by sowing in the greenhouse 5 days after treatment, 300 seeds for each treatment made on each of the three seed lots and by making a duplicate sowing 5 months after treatment, the seed meanwhile having been stored in cotton sacks in the laboratory. These data, along with those on infection, are presented in table 4.

TABLE 4.—*Effect of different methods of seed inoculation and seed treatments on emergence and covered smut in Tennessee Winter barley sown October 1934 in three series*

Treatment		Method of inoculation	Emergence from seed sown—		Heads infected with covered smut in—					
No.	Fungicide		5 days after treatment	5 months after treatment	Series 1 [1]		Series 2 [2]		Series 3 [3]	
			Pct.	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
1	Untreated	None	91	90	7	3.5	39	6.1	209	7.0
2	New Improved Ceresan	None	82	83	0	.0	0	.0	0	.0
3	Smuttox	None	77	78	0	.0	1	.2	5	.2
4	Ansul Dust	None	85	83	0	.0	4	.6	17	.7
5	P. A. C. Dust	None	86	90	0	.0	2	.3	44	1.8
6	Formaldehyde	None	91	86	0	.0	8	1.1	53	2.0
1	Untreated	Dry spores	89	90	9	4.4	68	11.3	585	16.4
2	New Improved Ceresan	Dry spores	81	88	0	.0	0	.0	0	.0
3	Smuttox	Dry spores	87	90	0	.0	11	1.8	94	2.8
4	Ansul Dust	Dry spores	87	90	0	.0	14	2.3	184	5.9
5	P. A. C. Dust	Dry spores	89	95	0	.0	24	3.7	177	5.3
6	Formaldehyde	Dry spores	87	66	0	.0	2	.3	35	1.1
1	Untreated	Spore suspension in vacuum.	89	97	12	5.9	113	18.2	540	20.7
2	New Improved Ceresan	Spore suspension in vacuum.	82	92	0	.0	0	.0	0	.0
3	Smuttox	Spore suspension in vacuum.	92	91	7	2.9	25	4.7	94	3.8
4	Ansul Dust	Spore suspension in vacuum.	90	93	13	5.0	105	16.0	516	18.0
5	P. A. C. Dust	Spore suspension in vacuum.	96	95	7	3.3	68	11.5	404	13.2
6	Formaldehyde	Spore suspension in vacuum.	87	64	1	.5	6	1.0	49	1.5

[1] Sown in rod rows at Statesville, N. C.
[2] Sown in small beds near greenhouse, Arlington Experiment Farm.
[3] Sown in field plots, Arlington Experiment Farm.

[4] LEUKEL, R. W. FACTORS INFLUENCING INFECTION OF BARLEY BY LOOSE SMUT. (In manuscript.)

None of the dusts caused any serious reduction in the percentage of germination, even when the seed was sown 5 months after treatment. New Improved Ceresan was the only treatment used that eliminated covered smut in all three series. Smuttox was more nearly satisfactory than the two other formaldehyde dusts. A 1-hour soak in a 1:320 formaldehyde solution was not sufficient to effect complete control of covered smut. The evacuation method of inoculating the seed caused a heavier infection and one less amenable to control by the formaldehyde dusts than did the dry-spore method.

Studies on control of black loose smut in 1934–35 were restricted to an experiment in the greenhouse bench.

Smut-free hand-threshed Alpha seed was inoculated with spores of *Ustilago nigra* by both methods previously mentioned. Four treatments were used and for each treatment that followed each inoculation method 250 seeds were sown. The data on germination and infection are shown in table 5.

TABLE 5.—*Emergence and loose smut in Alpha barley grown from seed inoculated by applying dry spores of Ustilago nigra to the seed or by immersing the seed in a spore suspension under vacuum* [1]

Treatment			Method of Inoculation	Germination	Heads		
No.	Fungicide	Rate per bushel			Grown	Smutted	
		Ounces		*Percent*	*Number*	*Number*	*Percent*
1	None		Dry spores	90	235	89	37.9
2	New Improved Ceresan	½		99	240	0	.0
3	Smuttox	3		99	251	3	1.2
4	Sulphur	3		99	252	75	29.8
5	Formaldehyde	(2)		95	240	0	.0
1	None		Evacuation	97	239	30	12.6
2	New Improved Ceresan	½		94	239	0	.0
3	Smuttox	3		98	251	0	.0
4	Sulphur	3		99	248	8	3.2
5	Formaldehyde	(2)		96	238	0	.0

[1] Inoculated seed was treated as shown and was sown in the greenhouse Dec. 4, 1934; data were taken Feb. 19, 1935.
[2] Seed soaked in a 1:130 solution for 1 hour.

In this case the evacuation method proved less effective than the dry-spore method for inoculating barley with spores of *Ustilago nigra*. As mentioned in a previous paper,[5] this is due probably to the fact that dusting with spores invests the seed with a spore load many times as great as that left by the evacuation method. New Improved Ceresan and formaldehyde eliminated loose smut in both series. Smuttox allowed three heads of loose smut to appear in one series, while sulphur was only 16 percent effective in the first series and 73 percent in the second. The fact that Jones (*6*) and Nattrass (*11*) found sulphur effective for covered smut control may possibly be explained by the prevalence of higher temperatures during and after treatment of the seed.

DISCUSSION

One of the outstanding features of the experiments on covered smut control described herein was the failure to secure high percentages of infection when using seed from badly infected fields. Three possible explanations are suggested: (1) Absence of conditions

[5] LEUKEL, R. W. See footnote 4.

favoring the fungus at harvesting and threshing and during the subsequent storage of the seed, (2) environmental conditions unfavorable for infection during the period of emergence, and (3) winter-killing of plants weakened by smut infection.

The seed used during the 1933–34 season, as previously stated under the heading Materials and Methods, underwent practically no so-called sweating process, so that very little spore germination may have taken place, the theory being that harvesting and threshing operations distribute the spores and that temperature and humidity conditions in the shock, stack, or bin may favor spore germination and the spread of the smut mycelium under the glumes.

The seed used in 1934–35 was taken from the bin 2 months after threshing, and this fact may account for the slightly higher percentage of smut obtained. In both seasons (*3*) it seems the soil conditions after sowing were reasonably favorable for infection, but winter-killing was severe and poor stands were obtained in the spring. Zade (*17*), working on latent infection by *Helminthosporium gramineum* in several barley varieties, *Ustilago avenae* in oats, and *Tilletia tritici* in wheat, suggested that the consequent weakening of the infected plants made them susceptible to winter injury.

The evacuation method of inoculating barley with covered smut seems to offer possibilities in seed-treatment studies. It caused not only a heavier infection than the dry-spore method but also a more deep-seated inoculation, judging by the poorer control effected by most of the treatments. Tapke (*15*), using a spore-suspension method without the use of a vacuum, secured as high as 70-percent infection in spring barley and slightly less in winter barley grown in the field. Whether or not this infection offered as adequate a test for fungicides as that caused by the evacuation method is not known, as Tapke made no seed-treatment studies. The failure of the evacuation method to produce higher percentages of covered smut in the above experiment may have been due partly to the high temperature (25°–28° C.) prevailing in the incubation chamber. Rump (*13*) found the minimum, optimum, and maximum temperatures for germination of spores of barley covered smut to be 5°, 20°, and 35° C., respectively.

In the limited studies on *Ustilago nigra*, inoculation by the dry-spore method seemed more effective than that by the evacuation method. Extensive studies in the field, however, might have yielded different results.

Ceresan and New Improved Ceresan were the only fungicides that proved entirely satisfactory in the control of covered smut and black loose smut throughout the experiments. Some of the formaldehyde dusts proved fairly effective at times but not consistently so. Fresh material was obtained every fall for use on winter barley. It was kept in the laboratory, in practically airtight containers, during the winter so that when used on spring barley it was less than 6 months old, and, according to the claims of some of the manufacturers, it should not have deteriorated. Koehler[6] states that he used three lots of formaldehyde dust in oat smut control experiments. One was fresh from the manufacturer, another had been stored in the refrigerator 1 year, and a third had been stored on the

[6] Benjamin Koehler, associate chief in crop pathology of the Illinois Agricultural Experiment Station, in written communication.

laboratory shelf 1 year. The percentages of infection were 0.3, 0, and 4, respectively, with 4.3 in the controls. He suggests that unless the can is hermetically sealed changes in temperature will cause air movements in and out of the can, so that in time sufficient fumes will escape to render the dust ineffective. Therefore, to insure the best results with formaldehyde dust, it seems that a fresh supply should be obtained each season.

Immersion of the seed in a 1:320 formaldehyde solution for 1 hour did not entirely eliminate covered smut, although it furnished complete control of black loose smut. Immersion for at least 2 hours is recommended.

SUMMARY

In 2 consecutive years barley from fields badly infected with covered smut produced crops with very low percentages of smutted heads.

Inoculation by the evacuation method or by applying dry spores to the seed and subsequent incubation at 25° to 28° C. and a high humidity resulted in about two or three times as much covered smut as was caused by the application of spores by natural agencies only.

Inoculation of the seed by the evacuation method produced a higher percentage of covered smut than was obtained by applying dry spores to the seed, and the disease was less easily controlled.

Ceresan and New Improved Ceresan completely controlled covered smut and black loose smut. Soaking the seed in a 1:320 formaldehyde solution for 1 hour eliminated black loose smut and gave fair but not complete control of covered smut. Formaldehyde dusts were not consistently effective, but some brands gave better results than others.

None of the commercial dust fungicides used was injurious to the seed even when the latter was stored for 5 months after being treated.

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