TB 919 (1946) USDA TECHNICAL BULLETINS UPDATA
CHEMICAL SEED TREATMENTS FOR THE CONTROL OF CERTAIN DISEASES OF SORGHUM
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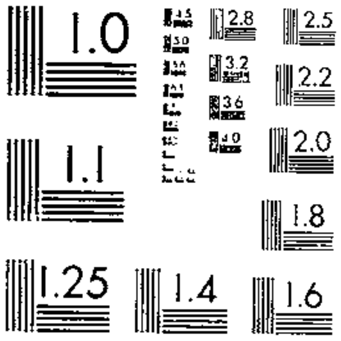

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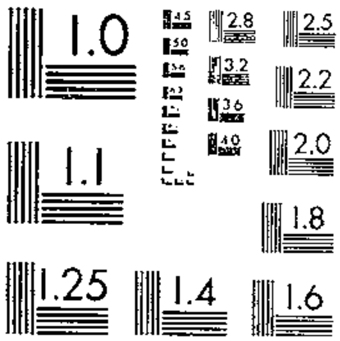

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Technical Bulletin No. 849 • 1943

UNITED STATES
DEPARTMENT OF AGRICULTURE
WASHINGTON, D. C.

Chemical Seed Treatments for the Control of Certain Diseases of Sorghum[1]

By R. W. LEUKEL, *pathologist, Division of Cereal Crops and Diseases, Bureau of Plant Industry, Soils, and Agricultural Engineering, Agricultural Research Administration*

The experiments and results reported in this technical bulletin are considered important at this time. Since it is printed under war conditions, when paper, labor, and machinery are scarce and time itself is at a premium, certain liberties have been taken with the form usually followed by the Department of Agriculture in scientific publications. The summary and the discussion of results are placed at the beginning instead of at the end, and the discussion of results is combined with the introduction. This compact front matter, which will give any reader a quick grasp of the work and its practical implications, is printed in the usual 10-point type. The more detailed descriptions of experiments follow and are printed in 8-point type. In addition to this mechanical saving of space, the descriptive material has been presented as briefly as seems consistent with retaining its scientific value. The tolerance of readers for this wartime arrangement is solicited.

GOVE HAMBIDGE,
Agricultural Research Administration.

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SUMMARY

Nineteen materials were tried as disinfectants for sorghum seed to determine their effect on emergence and on smut control during the 5-year period 1937–41.

In severely infested soil in the greenhouse, dust fungicides usually were most effective in improving emergence when they were applied at an excess rate, although they were also beneficial at the recommended rate. In less severely infested greenhouse soil and in field plots, however, benefits to emergence from the heavier dust applica-

[1] Submitted for publication November 1942.

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tions were no greater than from applications at recommended rates.

In soil heavily infested with species of *Pythium*, dust disinfectants, even when applied in excess, were relatively ineffective in improving emergence at 15° C. and also, to a great extent, at 20°.

In greenhouse soil infested with species of *Fusarium*, improvement in emergence as a result of seed treatment with the more effective dust fungicides was usually slight at 15° C. and very pronounced at 20° and 25°, especially when the excess rate of application was used.

The average improvement in emergence following treatment with nine dust fungicides of seed of nine varieties planted on four dates ranged from 11.6 percent for New Improved Semesan Jr. to 39.5 percent for copper carbonate and averaged 26.4 percent for the fungicides used, which comprised six mercury and three copper compounds, all applied at a rate of 2 ounces per bushel.

INTRODUCTION AND DISCUSSION OF RESULTS

The importance of sorghum as a food and feed crop has been enhanced by the Government's food program. Therefore, the publication and dissemination of the information contained in this bulletin to research and extension workers are especially timely as these data should contribute to better sorghum production.

Recent investigations (*8*)[2] have shown that the all too common poor stands of sorghum result from seed-borne and soil-borne fungi.

Relatively few of the vast number of experiments on seed treatment within the past decade have been devoted to sorghum. Many of the limited data found in the literature on sorghum seed treatment deal with the use of formaldehyde and copper sulfate solutions or with obsolete or commercially unavailable fungicides. Consequently, in 1937, experiments on sorghum seed treatment with some of the more recently developed seed disinfectants were started at the Arlington Experiment Farm, Arlington, Va.

The results of these experiments, which are reported in this bulletin, show that treating sorghum seed with fungicides before planting not only improves stands by combating the seed-borne or soil-borne organisms but also prevents the occurrence of loose and covered kernel smuts in the mature crop.

The data presented in tables 1 to 7, inclusive, show that under the conditions of these greenhouse experiments treatment of sorghum seed with certain dust fungicides generally was followed by considerable improvement in emergence compared with that from untreated seed. The fungi combated by the dust fungicides were chiefly those already present in the soil, as is shown by the excellent emergence from untreated seed planted in sterilized soil, even at 15° C. (see table 2). That seed-borne organisms also may impair emergence, however, is demonstrated by the fact that seed treatment with dust fungicides at times was followed by greatly improved emergence even in sterilized soil (see table 1), but when the seed was first surface-sterilized in sodium hypochlorite the beneficial effects of dust fungicides on seed in sterilized soil were less evident (see tables 2, 3, and 4).

The effect of temperature and, to some extent, of moisture on emergence and on the benefits derived from the use of dust fungicides is also brought out in some of the experiments (see tables 3 and 4).

[2] Italic numbers in parentheses refer to Literature Cited, p. 24.

At 15° C., in soil infested with virulent fungi, the use of the better dust fungicides generally was followed by increases in the percentages of emergence that were relatively large compared with emergence from untreated seed, which, at that temperature, germinated very poorly. At 20° and, to a less extent, also at 25°, the more effective dust fungicides caused increases in the average percentages of emergence that were much larger than those at 15°, but, because of better emergence from untreated seed at these temperatures, the relative increases were less impressive than those at 15°. In general, the absolute increase in emergence from treated seed was greatest at 20° and least at 15°, whereas the relative increase was greatest at 15° and least at 25°. Large increases usually were obtained when the soil was badly infested and the fungicides were applied by the excess method.

In a late planting in the greenhouse in less severely infested soil and in three field plantings in 1937 in which the dust fungicides had been applied at generally recommended rates, increases in the percentages of emergence due to treatment were less pronounced than in the previous greenhouse experiments in badly infested soil. (See tables 8, 9, and 10.) Again in 1940 (see table 15) statistically significant increases in emergence followed the application of three or four times the usually recommended amount of dust fungicides to seed planted in heavily infested greenhouse soil, indicating that better emergence should follow the use of relatively heavy applications of most of the dust fungicides than is obtained from the rate generally recommended. However, in less severely infested soil in greenhouse and field experiments in 1940, in which three rates of application were again used, no consistent additional benefits to emergence followed the use of the heavier rates of application, and in some cases there were indications of injurious results. These differences in results are attributed to differences in variety, temperature, moisture, and the degree of soil infestation. They suggest the advisability of applying certain dust fungicides at two or more times the recommended rate when seed is to be planted in cold soil that is heavily infested with injurious fungi.

The failure to control covered kernel smut satisfactorily in 1937 and 1938 with dust fungicides applied at the rate of 2 or 3 ounces per bushel (see tables 10 and 11) may be attributed to the lack of sufficient fungicidal dust to inactivate all of the smut spores on the seed under the apparently ideal conditions for smut development prevailing during emergence. In such an environment the heavy spore dosage employed imposed an exceptionally severe test on the ability of the fungicides to prevent infection.

In the experiments of 1939, 1940, and 1941, environmental conditions apparently were less favorable for smut development than in 1937 and 1938 (see tables 14, 15, 16, and 18), or possibly more conducive to fungicidal efficiency, and more satisfactory control was obtained.

In actual farm practice, sorghum seed carrying a spore dosage of 1 to 100 is rarely, if ever, planted, and, therefore, a similar failure to control smut with the better dust fungicides, if properly applied, could hardly occur under average farm conditions.

In field experiments in 1937 and 1938, with a few exceptions, extremely poor control of covered kernel smut followed the use of dust fungicides applied to heavily smutted seed of different varieties at 2 or 3 ounces per bushel. Subsequent experiments under controlled environment indicated that conditions extremely favorable for smut infection and possibly not conducive to smut control, along with a heavy spore dosage and a high percentage of seed with adherent hulls, were responsible for this lack of adequate control. The dust fungicides most nearly effective in controlling smut under these critical conditions were: New Improved Ceresan, Merko, copper carbonate, basic copper sulfate, cuprous oxide, Ceresan, New Improved Semesan Jr., and sulfur. In experiments in 1939 and 1940, most of these materials controlled smut satisfactorily. Sanoseed and the Barbak seed-corn disinfectants, together with several other fungicidal dusts, while effective in promoting emergence, failed to show promise as smut preventives. On the other hand, sulfur, which failed to increase emergence appreciably, controlled smut effectively. Basic copper sulfate, cuprous oxide, New Improved Ceresan, copper carbonate, and Spergon appear to be effective for improving emergence and also for controlling covered kernel smut.

Chlorine gas, sodium hypochlorite, and formaldehyde solutions controlled smut effectively, but their use is not recommended because of inconvenience of application, cost, or seed injury.

The presence of glumes on sorghum seed reduced the thoroughness of smut control by nonvolatile dust fungicides.

Planting smutted seed in soils the moisture content of which had been adjusted to 30-, 50-, and 70-percent saturation resulted in 26.8, 81.6, and 5.6 percent smut infection, respectively, indicating that soil about half saturated is much more conducive to smut development than extremely wet or dry soil.

Seed injury due to treatment with New Improved Ceresan seemed to depend more on variety and rate of application than on length of period of storage after treatment. When seed was planted 1 month after being treated at ½, 1, and 1½ ounces per bushel, emergence in Leoti sorgo was reduced 5.3, 26.7, and 30.7 percent, respectively, and 11.7, 23.6, and 36.5 percent, respectively, of the seedlings that emerged showed mercury injury. In Sharon kafir there was no reduction in emergence and only 1.1, 1.8, and 5.0 percent, respectively, of the seedlings showed mercury injury. A longer period of storage did not result consistently in an increase in injury.

Spergon, a recently developed nonmetallic organic seed disinfectant containing 99 percent tetrachloro-para-benzoquinone, in two separate experiments in 1 year perfectly controlled covered kernel smut and greatly improved emergence without any indication of seed injury. In one experiment 5. percent and in the other 37 percent of the untreated checks were smutted.

REVIEW OF LITERATURE

Formaldehyde and, to some extent, copper sulfate solutions were for many years the principal, if not the sole, fungicides used for treating sorghum seed. Johnston and Melchers (5) conducted extensive experiments from 1918 to 1925, designed chiefly to determine the safest and most effective method of using formaldehyde for this purpose. A 1-hour soak in a 1 to 240 solution seemed to give the best results over a 5-year period. A number of proprietary compounds, most of which are now obsolete, containing organic mercury, phenol, cresol, or other materials in solution were found to be fairly effective in smut control. Nineteen dust fungicides were tried and at least 12 of them proved effective. Chief among those now available commercially were copper carbonate, dehydrated copper sulfate, and sulfur. These materials, applied at a rate of 2 ounces per bushel, limited the smut to an average of less than 2 percent of the plants in 4 varieties, while an average of from 12 to 17 percent of the plants from untreated seed were infected with smut. Finnell (*4*), in 1926, reported that copper carbonate and Bayer Dust, when applied to the seed at the rate of 4 ounces per bushel, greatly improved stands. Kamat (*6*), in 1927, secured control of smut in India with Germisan. Swanson and Getty (*15*), in 1930, used Uspulun and Semesan in solution and copper carbonate and Bayer Dust as dust fungicides to improve stands in feterita, kafir, and sorgo. Uppal and Desai (*17*), in 1931, reported from India that copper carbonate and sulfur were used successfully to prevent smut in sorghum. Dehydrated copper sulfate also was effective but, because of absorption of moisture, did not retain its powdered form and hence was not recommended. Wallace (*18*), in 1931, in Tanganyika, recommended immersing the seed in a 2-percent copper sulfate solution for 15 minutes or in a 0.5-percent formaldehyde solution for 2 hours. Plymen (*13*), in 1933, reported from India that copper carbonate was considerably more effective than sulfur in smut control. Takasugi and Akaishi (*16*), in 1933, reported that in Manchuria, sorghum smut was effectively controlled by immersing the seed in solutions of formalin, copper sulfate, Semesan, Uspulun, Tillantin, or lime-sulfur for the proper periods. McDonald (*11*), in 1936, stated that in Kenya, Africa, sorghum seed dusted with Abavit B and Bayer Dust reduced the occurrence of smut from 26.4 percent to 1.2 and 2.1 percent, respectively. An anonymous report (*1*) from Berar, in 1936, indicated that copper carbonate, sulfur, Abavit B, Ceresan, and Agrosan G reduced the incidence of covered smut from 11.2 percent to less than 0.3 percent.

Henderson,[3] in 1941, reported that in Colorado complete control of sorghum kernel smut was obtained with New Improved Ceresan and yellow oxide of mercury, and that copper carbonate and cuprous oxide reduced it to less than 1 percent. From 23 to 33 percent of the plants from untreated seed were infected. The seed treatments were reported to have increased the stand by amounts ranging from 38.5 to 108 percent of the stand from untreated seed.

El-Helaly (*2*), in 1939, in extensive field experiments at Dakki, Egypt, tried Germisan, Uspulun, formaldehyde, copper sulfate, copper acetate, copper nitrate, and copper chloride in solutions, and sulfur, copper carbonate, cuprous chloride, cuprous iodide, mercuric iodide, and Agrosan G as dusts. All materials used as solutions gave satisfactory smut control as also did the dust Agrosan G. None of the other dusts was found satisfactory. Cuprous chloride and cuprous iodide increased susceptibility to smut infection, and mercuric chloride severely injured the seed. The infection from untreated smutty seed ranged from 0 to 35 percent, depending on the rate of inoculation and the time of planting.

A number of additional brief references to sorghum smut control found in annual reports of investigators in Egypt, India, and China recommend formaldehyde, copper carbonate, and sulfur most frequently for the control of sorghum kernel smut. Little mention is made of the use of seed treatments for the purpose of obtaining better stands.

MATERIAL AND METHODS

Seed Used

In the greenhouse studies on the effect of treatment on emergence, feterita was mostly used. This variety has a large seed with a relatively thick, soft seed coat, which makes it very susceptible to attack by decay organisms when it is planted in a cold, wet soil (*8, 15*). In similar studies in the field the following named varieties were used: Spur feterita, Club, Chiltex, and Darso from Lawton, Okla.; Kansas Orange sorgo from Chillicothe, Tex.; Dwarf hegari from Woodward, Okla.; and Sharon kafir, Dwarf Yellow milo, and Sumac sorgo from the Arlington Experiment Farm, Arlington, Va. In the studies on smut control, kafir, broomcorn, and sorgo types were used. Sharon kafir was used all 5 years; Black Spanish broomcorn was used in 1937 and Scarborough broomcorn in 1938 and 1939; Kansas Orange sorgo and Sumac sorgo were used in 1937; and Leoti sorgo in 1938, 1939, and 1940.

Inoculation of Soil and Seed

In certain greenhouse studies soil was used that had been prepared previously for studies on seed rot and damping-off in sorghum (*8*). This soil had been sterilized at 15 pounds steam pressure for 2 hours on each of 2 days, and separate portions had been inoculated with cultures of fungi, mostly isolations of *Pythium* spp. and *Fusarium* spp. that had been found capable of causing seed rotting or damping-off in sorghum. This inoculated soil was stored in large covered metal cans in a

[3] Henderson, W. J. Demonstrations show value of sorghum seed treatment in Colorado. Ext. Pathologist 46: 30-32. 1941. [Processed.]

basement. Supplies of uninoculated sterilized and unsterilized soils used as checks were similarly stored.

For the studies on smut control, heads of sorghum plants infected with covered kernel smut were collected the previous summer, dried in the greenhouse, broken up, and sifted through a 60-mesh sieve. The smut was stored in glass containers in a refrigerator at 10° C. until used. In 1937, 1938, and 1941, the seed was inoculated at a spore dosage of 1 to 100, that is, 1 gm. of smut to 100 gm. of seed. In 1939 and 1940, spore dosages of 1 to 300 and 1 to 600 also were included.

Seed Disinfectants

Nineteen materials were tried as seed disinfectants during the 5-year period Of these, 8 contained mercury, 4 contained copper, 3 chlorine, 1 sulfur, 1 zinc, and 1 formaldehyde. Two of these materials were tested for 5 seasons, 1, 2, and 3 were tried for 4, 3, and 2 years, respectively, and 11 were limited to a 1-year test.

The materials containing mercury were Ceresan (2 percent ethyl mercuric chloride), New Improved Semesan Jr. (1 percent ethyl mercuric phosphate), New Improved Ceresan (5 percent ethyl mercuric phosphate), Barbak III (10 percent mercuric phenyl cyanamide plus 5 percent lead diethyl dithiophosphate), Barbak 36-32-B (5 percent cadmium carbonate and 10 percent mercuric phenyl cyanamide), Barbak C (2.5 percent cadmium oxide and 8 percent mercuric phenyl cyanamide), Merko (3.5 percent mercury in inert material), and Sanoseed (2 percent ethanol mercuric chloride).[4] The materials containing copper were copper carbonate, basic copper sulfate, cuprous oxide, and copper oxychloride. The remaining materials were: Vasco 4 (58 percent zinc oxide, 10 percent zinc hydroxide, and 4 percent zinc sulfide), sodium hypochlorite, chlorine gas, sulfur, formaldehyde, and Spergon (99 percent tetrachloro-para-benzoquinone). Two materials containing sodium hypochlorite were used: A commercial product called "M. E. Chlorine," containing among other ingredients 7.6 percent sodium hypochlorite, and Hyclorite, a commercial 4-percent sodium hypochlorite solution. Chlorine gas was included in connection with studies (9) made of this material at that time.

In the preliminary greenhouse experiments, the fungicidal dusts were applied by the excess method, that is, an excess amount of each chemical dust was applied to a separate portion of seed, which was thoroughly shaken and the excess dust then removed by sieving. A bushel of seed may thus retain from 4 to 10 ounces of dust, depending upon the specific gravity and fineness of the dust, the size of the seeds, and the characteristics of the seed coats. In the field experiments in 1937 and 1938, the recommended quantity of each dust was weighed and applied to a weighed quantity of seed. In 1939, five of the dusts were applied by the excess method, but New Improved Ceresan was applied at the rate of one-half ounce per bushel several days before planting by placing the relatively small quantity of seed to be planted in a loosely tied cheesecloth sack and burying it in a half bushel of seed, which was then treated with the same material at the rate of one-half ounce per bushel in a rotary mixer.

In emergence studies involving different temperatures, several portions of 100 seeds each from each treated lot were planted 1 inch deep in separate metal boxes, 4 by 8 inches and 3 inches deep. These were placed in metal pans, 26 by 12 by 4 inches, lined with moist blotters and covered to keep the soil moisture constant during germination and emergence. At the time of emergence the metal cover was replaced by glass and artificial light was used to maintain growth. The constant temperatures were maintained by artificial refrigeration or thermostatically controlled heaters in specially constructed chambers.

In studies in the greenhouse the seed was planted 1 to 1½ inches deep in soil adjusted to about 50 percent of its water-holding capacity. The temperature ranged from 18° to 28° C. during emergence but was maintained as near 20° as possible. Data on stand were taken 7 to 14 days after planting.

In the field experiments on the effect of seed treatment on stand, 200 seeds were planted per 10-foot row. There were 3 replications for each treatment applied to each variety planted on each of 3 dates.

In the experiments on smut control, the seed was planted by hand at the rate of about 250 seeds per 44-foot row. Later the plants were thinned to the proper stand. In 1937, three replications were used; in 1938 and 1941, a single replication was planted on each of 2 dates; and in 1939 and 1940, a 44-foot row was devoted to each fungicide used for each of 3 spore dosages on each variety. In 1937, data were taken on the percentage of smutted heads and, where possible, also on the percentage of smutted plants. In the following years the data on smut infection in the field experiments were limited to head counts.

[4] Germisan, a mercurial used in solution and at present not commercially available, was used in one experiment.

EXPERIMENTAL RESULTS

Effect of Seed Treatment on Seedling Emergence

In a preliminary experiment on the effect of seed-borne and soil-borne organisms on seedling emergence, each of several portions of seed of feterita was treated with 1 of 4 seed disinfectants and planted, along with untreated seed, in flats of soil in 2 parallel series in the greenhouse. In 1 series the soil had been sterilized and in the other it had not. Five flats were used for each lot of soil, and 500 seeds were planted per flat. The results, given in table 1, indicate that both seed-borne and soil-borne organisms were factors in reducing emergence. Germisan, used as a 0.25-percent solution, was most effective in improving stands where only the seed-borne organisms were involved, while Ceresan was most effective where both seed-borne and soil-borne organisms were present. Formaldehyde treatment apparently increased the susceptibility of the seed to attack by soil organisms.

Table 1.—*Effect of seed disinfectants and soil sterilization on emergence of feterita in the greenhouse at 20° C., 1937*

Seed treatment		Emergence in soil	
Kind	Rate	Sterilized	Unsterilized
		Percent	*Percent*
None		27	9
Ceresan	Excess	79	51
Copper carbonate	do	56	48
Formaldehyde	1:240, 1 hour	53	4
Germisan	0.25 percent, 1 hour	83	37

To determine the effect of certain types of soil-borne organisms on emergence and the degree to which they can be combated by seed treatments, seed of Spur feterita was planted in sterilized soil that had been artificially infested with cultures of a number of unidentified species of *Pythium* or *Fusarium* isolated from soil (*8*). The seed was surface-sterilized in 2-percent sodium hypochlorite for 30 minutes to eliminate the effect of seed-borne organisms. Separate portions of this seed were dusted with different fungicides using the excess method and planted in the artificially infested soils and also in sterilized soil not artificially infested. According to the data given in table 2, the *Pythium* spp. were more injurious to emergence and less responsive to the fungicides than were the *Fusarium* spp. The mercury dusts seemed to be more effective than the copper dusts in improving stands.

Table 2.—*Effect of seed treatment with dust fungicides*[1] *on emergence of Spur feterita in sterilized soil artificially inoculated with Pythium spp. or Fusarium spp. and kept at an average temperature of 20° C., in the greenhouse at Arlington Experiment Farm, 1937*

Seed treatment[2]	Emergence in sterilized soil		
	Uninoculated	Inoculated with—	
		Pythium spp.	*Fusarium* spp.
	Percent	*Percent*	*Percent*
None	94	11	21
New Improved Semesan Jr.	97	20	87
Merko	93	20	95
Barbak 111	95	21	96
Barbak 36-32-B	98	24	91
Copper carbonate	96	16	73
Basic copper sulfate	97	14	67
Cuprous oxide	98	12	80
Ceresan	96	42	85
New Improved Ceresan[3]	96	38	80

[1] All the fungicides were applied by the excess method.
[2] The seed had first been surface-sterilized in 2 percent sodium hypochlorite for ½ hour, washed, and thoroughly dried.
[3] This fungicide was applied diluted with 4 parts of talc.

To test the effect of dust fungicides on emergence in infested soil at different temperatures, seed of Spur feterita, treated and untreated, was planted in four different lots of soil: (1) Sterilized and uninoculated; (2) sterilized and inoculated with *Pythium* spp.; (3) sterilized and inoculated with *Fusarium* spp.; and (4) unsterilized and uninoculated, but known to be naturally infested with various organisms deleterious to emergence in sorghum. One hundred seeds were planted for each combination of soil, seed treatment, and temperature. The results are given in table 3 and illustrated in figure 1.

FIGURE 1.—Effect of seed treatment and soil infestation on emergence in Spur feterita at 20° C. *A*, Sterilized, uninoculated soil; *B*, unsterilized, uninoculated soil naturally infested; *C*, sterilized soil inoculated with *Fusarium* spp.; *D*, sterilized soil inoculated with *Pythium* spp. Seed treatments: *a*, None; *b*, New Improved Semesan Jr.; *c*, Merko; *d*, Barbak 111; *e*, Barbak 36-32-B; *f*, copper carbonate; *g*, basic copper sulfate; *h*, cuprous oxide; *i*, Ceresan; *j*, New Improved Ceresan.

TABLE 3.—*Effect of soil temperature, soil infestation, and seed treatment with dust fungicides on emergence in Spur feterita, 1937*

Soil temperature (° C.)	Emergence from seed treated [1] with—									Average emergence from seed		Increase in average percentage of emergence from treated seed
	New Improved Semesan Jr.	Merko	Barbak 111	Barbak 36 22-B	Copper carbonate	Basic copper sulfate	Cuprous oxide	Ceresan	New Improved Ceresan [2]	Treated	Untreated	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
IN SOIL STERILIZED AND UNINOCULATED												
15	84	90	98	95	92	88	88	90	73	88.7	72	16.7
20	98	93	94	98	96	98	99	97	95	96.4	92	4.4
25	96	94	96	99	96	99	97	95	97	96.6	95	1.6
IN SOIL STERILIZED AND INOCULATED WITH PYTHIUM SPP.												
15	0	0	0	0	0	0	0	0	0	0	0	0
20	10	0	4	10	0	0	1	39	30	10.4	0	10.4
25	73	54	62	69	40	38	34	85	85	61.0	22	39.0
IN SOIL STERILIZED AND INOCULATED WITH FUSARIUM SPP.												
15	10	2	3	39	11	9	0	27	12	12.6	0	12.6
20	85	54	61	78	66	60	45	95	84	70.8	22	48.8
25	94	84	74	83	87	82	87	95	90	86.2	64	22.2
IN SOIL NEITHER STERILIZED NOR INOCULATED BUT NATURALLY INFESTED												
15	7	0	0	8	22	3	6	61	5	12.4	0	12.4
20	81	51	49	61	57	64	51	97	95	67.3	11	56.3
25	93	73	82	92	87	83	81	98	96	87.2	66	21.2
INFESTED SOIL (AVERAGES)												
15	6	1	1	16	11	4	2	29	6	8.4	0	8.4
20	59	35	38	50	41	44	32	77	70	49.6	11	38.6
25	87	70	73	81	74	68	67	93	90	78.1	51	27.1

[1] All seed was surface-sterilized in 2 percent sodium hypochlorite for ½ hour, washed, and dried. The dusts were applied by the excess method.
[2] Diluted with talc so as to contain 1 percent of ethyl mercuric phosphate.

In the sterilized uninoculated soil, emergence, with two exceptions, was excellent at all three temperatures, even from seed not treated with any of the dust fungicides. Nevertheless, at 15° C., seed treatment with the dust fungicides increased the percentages of emergence by amounts ranging from 1 to 26 and averaging 16.7. At 20° and 25°, the average percentage emergence from seed dusted with the fungicides was only slightly better than that from seed not so treated.

In the soil infested with *Pythium* spp., at 15° C. emergence was entirely inhibited irrespective of treatment, and at 20° emergence from treated seed ranged from 0 to 39 percent, the average being only 10.4 percent. At 25° the average percentage of emergence from treated seed was 61, which was 39 above that from untreated seed.

In the soil infested with *Fusarium* spp. there was no emergence from untreated seed at 15° C., and that from treated seed ranged from 2 to 39 percent, the average being only 12.6 percent. At 20° the average percentages of emergence from untreated and treated seeds were 22 and 70.8, respectively, and at 25° they were 64 and 86.2, respectively. Similar results were obtained in the unsterilized, naturally infested soil; with one exception little or no emergence occurred at 15°, the treatments brought about a considerable increase at 20°, and a smaller increase at 25°.

In a later, similar experiment, sterilized soil was inoculated with a number of common soil-infesting pathogens. Because of lack of available space in the constant temperature chambers, the seed treatments were limited to one organic mercury dust, two copper dusts, and sulfur. The seed was first surface-sterilized in a 1:320 formaldehyde solution for 30 minutes, thoroughly washed, and then dried to a moisture content of less than 11 percent. The copper and sulfur dusts were applied by the excess method, but New Improved Ceresan was applied at the rate of three-fourths of an ounce per bushel. Emergence data are given in table 4.

TABLE 4.—*Effect of soil temperature, soil infestation, and seed treatment with dust fungicides on emergence in feterita*

Soil			Emergence from seed—				
				Dusted with—			
Inoculum added	Saturation	Temperature	Untreated	New Improved Ceresan	Copper carbonate	Cuprous oxide	Sulfur
	Percent	°C.	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
None (soil sterilized)	70.0	15	22	44	45	30	13
		20	61	70	72	70	50
		25	71	64	81	75	64
None (soil unsterilized)	65.0	15	3	0	48	25	1
		20	13	36	54	52	11
		25	60	76	75	75	40
Fusarium culmorum	58.6	15	1	35	6	2	0
		20	2	68	10	14	4
		25	24	63	67	62	25
Fusarium moniliforme (*Gibberella fujikuroi*)	54.0	15	5	44	9	20	1
		20	32	75	42	57	35
		25	60	89	67	75	45
Penicillium oxalicum	51.2	15	16	51	31	45	17
		20	42	65	61	63	60
		25	56	78	78	75	66
Rhizoctonia solani	58.6	15	0	8	3	6	0
		20	22	27	42	30	21
		25	26	46	39	41	33
Sclerotium bataticola	47.6	15	26	62	40	40	13
		20	51	63	72	72	60
		25	60	84	82	56	71
Pythium debaryanum	62.5	15	0	0	0	0	0
		20	3	10	16	13	2
		25	42	64	65	71	40
Pythium arrhenomanes	51.2	15	0	0	30	22	0
		20	8	45	40	52	12
		25	76	84	87	84	56
Average in infested soil		15	6.4	25.0	20.9	20.0	4.0
		20	22.0	48.6	42.1	44.1	25.6
		25	51.6	73.0	70.0	71.1	47.0

The attempt to adjust the different lots of soil to approximately the same percentage of saturation was not entirely successful, especially with respect to the sterilized, uninoculated portion. The percentages of emergence in the latter soil were depressed somewhat by the high moisture content, and hence comparison of these results with those obtained in the different lots of inoculated soil probably does not reveal the full effects of the fungi on emergence.

At 15° C. all the fungi, except *Sclerotium bataticola* and *Penicillium oxalicum*, greatly reduced emergence, and in some cases the dust fungicides were of little or no benefit. However, in the eight lots of infested soil, the average percentages of emergence from seed treated with New Improved Ceresan, copper carbonate, and cuprous oxide were 25.0, 20.9, and 20.0, respectively, compared with 6.4 percent from untreated seed. At 20° the corresponding average percentages of emergence were 48.6, 42.1, 44.1, respectively, compared with 22.0 from untreated seed; and at 25° they were 73.0, 70.0, and 71.0, respectively, compared with 51.6 from untreated seed. Emergence from sulfur-treated seed in infested soil averaged slightly less at 15° and 25° and slightly greater at 20° than emergence from untreated seed. From this it seems that sulfur is ineffective against the soil fungi in question. The mercury dust seemed to be more effective against the two species of *Fusarium* than were the copper dusts, and the copper fungicides seemed to be the slightly more effective in combating the two species of *Pythium*.

These results show that soil-borne pathogens are largely responsible for poor emergence from viable sorghum seed, especially when it is planted in cold soil (*8*). However, the relatively poor emergence in the wet, sterilized, uninoculated soil seems to indicate that excessive soil moisture and the accompanying reduced aeration also tend to inhibit emergence.

Additional data on the effect of seed treatment end soil temperature on emergence in the presence of soil-borne organisms were obtained in experiments in soils obtained from a number of stations in the sorghum-growing areas of Oklahoma, Texas, and Kansas. The fields from which these soils came had been planted to sorghum continuously for periods ranging from 6 to 23 years (*8*). The soils ranged from light sandy soil, low in organic matter, to rich black soil, high in organic matter. Keyport clay loam from Arlington Farm was included. Treated and untreated seed of feterita was planted in portions of each of these soils maintained at three temperatures, 15°, 20°, and 25° C. An attempt was made to adjust the moisture content of each soil lot to about 50 percent of its previously determined water-holding capacity. The resulting percentages of saturation, however, ranged from 46 to 65. The portions of soil that were steam-sterilized took on additional moisture during sterilization, so that their moisture content ranged from 51 to 80 percent of saturation. To these differences in soil-moisture content are attributed some of the more or less inconsistent results obtained as shown in table 5.

TABLE 5.—*Effect of soil temperature, soil sterilization, and seed treatment with dust fungicides on emergence of feterita planted in the greenhouse at Arlington Experiment Farm in soils taken from different localities*

Soil				Emergence from seed—					
					Treated with—				
Source	Water-holding capacity	Saturation[1]	Temperature	Untreated	New Improved Ceresan	Copper carbonate	Cuprous oxide	Sulfur	Untreated but planted in sterilized soil[2]
	Percent	Percent	°C.	Percent	Percent	Percent	Percent	Percent	Percent
Lawton, Okla	37	46	15	3	3	25	45	0	50
			20	58	82	77	80	35	60
			25	78	85	76	88	80	71
Woodward, Okla	22	51	15	14	18	52	46	15	62
			20	66	89	88	81	65	72
			25	74	92	77	89	79	77
Chillicothe, Tex	31	61	15	12	27	19	55	25	58
			20	59	91	83	89	75	61
			25	67	86	82	81	75	67
Hays, Kans	43	55	15	28	53	44	45	11	55
			20	63	79	76	80	66	59
			25	65	86	81	86	77	69
Garden City, Kans	42	54	15	27	50	35	46	24	57
			20	61	83	89	83	65	64
			25	73	84	89	87	68	76
Manhattan, Kans	41	57	15	0	3	9	36	0	44
			20	36	72	75	79	20	52
			25	73	89	86	90	74	72
Arlington, Va	38	65	15	0	11	0	20	0	42
			20	13	72	62	64	14	56
			25	34	84	70	86	54	76
Mixture (inoculated)[3]	37	62	15	0	0	0	0	0	41
			20	0	18	43	56	2	57
			25	21	78	74	84	34	76
Averages	...	56.4	15	10.5	20.6	23.0	36.6	9.4	51.1
			20	44.5	73.3	74.1	76.5	42.8	60.1
			25	60.6	85.5	80.5	86.4	67.6	73.0

[1] Expressed as percentage of water-holding capacity but does not apply to sterilized soil.
[2] Sterilized at 15 pounds pressure for 30 minutes; water content averaged 70-percent saturation.
[3] This was a mixture of soil lots used in other experiments and artificially inoculated with various fungi, especially species of *Pythium*.

The two copper dusts applied by the excess method improved emergence slightly more than did New Improved Ceresan applied at three-fourths of an ounce per bushel. No consistent benefits were derived from the use of sulfur.

The average increases in the percentages of emergence at 15°, 20°, and 25° C., from seed treated with the copper and mercury dusts over those from untreated seed were 16.2, 30.1, and 23.5, respectively. The corresponding average increases in the percentages of emergence from untreated seed in sterilized soil over those in unsterilized soil were 40.6, 15.6, and 12.4, respectively. The sterilized soil, however, was too wet for optimum emergence. The tests were repeated later in portions of these different soils, sterilized and adjusted to about 50 percent saturation. The average percentages of emergence in this case from the same lot of untreated seed at 15°, 20°, and 25° C. were 65, 88, and 93, respectively, compared with 51.1, 60.1, and 73.0, respectively, the corresponding averages given in table 5.

The experiments thus far had been confined to soil in relatively small containers in which it was difficult to maintain uniform moisture conditions. As an approach to field conditions, an experiment was conducted in a greenhouse bench in soil adjusted to about 55 percent saturation. The soil in half of the bench (series 1) was mixed with small lots of soil that had been inoculated with different fungi and used in other experiments (8). The soil in the remainder of the bench (series 2), while not inoculated, was known to be abundantly infested. As shown later, the small quantity of inoculum apparently had little effect on emergence and, therefore, the results from the two series are averaged and discussed together.

Two lots of seed of Spur feterita were used. One lot from Lawton, Okla., was of excellent viability and was surface-sterilized in 2 percent sodium hypochlorite for 30 minutes. The other lot from Chillicothe, Tex., was lower in viability and was not surface-sterilized. Three hundred seeds of each lot were used in each series for each of nine fungicides, which were applied by the excess method. The data on emergence are given in table 6.

TABLE 6.—*Emergence of Spur feterita from seed from Lawton, Okla., and Chillicothe, Tex., treated with dust fungicides by the excess method and planted in a greenhouse maintained at an average temperature of 20° C., but ranging at times from 15° to 28°*

Seed treatment [1]	Emergence from seed from—									
	Lawton, Okla.[2]					Chillicothe, Tex.				
	Series 1 [3]	Series 2	Average	Increase from treatment		Series 1 [3]	Series 2	Average	Increase from treatment	
				Absolute	Relative				Absolute	Relative
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
None	32	35	33.5	-----		6	15	10.5	-----	--
New Improved Semesan Jr	77	88	82.5	49.0	146.3	43	46	44.5	33.5	304.5
Merko	89	93	91.0	57.5	171.6	52	49	50.5	39.5	359.1
Barbak 111	96	97	96.5	63.0	188.1	54	61	57.5	46.5	422.7
Barbak 30-32-B	90	93	91.5	58.0	173.1	59	61	60.0	49.0	445.5
None	31	36	33.5	-----	--	11	12	11.5	-----	
Copper carbonate	91	95	93.0	59.5	177.6	66	65	65.5	54.5	495.5
Basic copper sulfate	87	94	90.5	57.0	170.1	65	65	65.0	54.0	490.9
Cuprous oxide	91	92	91.5	58.0	173.1	58	61	59.5	48.5	440.9
Ceresan	90	94	92.0	58.5	174.6	56	60	58.0	47.0	427.3
New Improved Ceresan [4]	81	89	85.0	51.5	153.7	52	56	54.0	43.0	390.9
Average for treated seed	88	92.8	90.4	56.9	169.9	56.1	58.2	57.2	46.2	419.7

[1] All the fungicides were applied by the excess method.
[2] Seed from Lawton was first surface-sterilized in 2 percent sodium hypochlorite for 30 minutes.
[3] Soil in series 1 was mixed with soil artificially inoculated with various organisms; that in series 2 received no additional inoculum.
[4] Diluted with talc so that it contained only 1 percent of ethyl mercury phosphate.

Emergence from the Lawton seed not dusted with any fungicide was 33.5 percent, and that from the dusted seed averaged 90.4 percent, an increase of 56.9. Emergence from untreated Chillicothe seed was only 10.5 percent, while the average emergence from the same seed dusted with fungicides was 57.2 percent, an increase of 46.7.

Experiments were next designed to test the effect of these fungicides on emergence under field conditions. Differences in soil temperature were obtained by planting on different dates. No attempt was made to surface-sterilize the seed. Separate portions of seed of each of 9 varieties were treated with dust fungicides at the rate of 2 ounces per bushel on April 19, 1937, and stored in open glass jars until counted out into unsealed envelopes ready for planting. Unusually heavy and frequent rains prevented the first scheduled field planting, and it became necessary to plant in the greenhouse bench instead. The badly infested soil in the greenhouse bench had been removed, and the bench had been refilled with soil from the field. For each fungicide, 300 seeds of each variety were planted April 29, 1½ inches deep. The soil temperature ranged from 16° to 35° C., but usually was kept at about 24°. The emergence data taken May 11 are given in table 7. The benefits from seed treatment, on the whole, were less pronounced than those obtained in the previous experiments in which the dusts had been applied by the excess method. However, appreciable increases in the percentages of emergence, ranging from 9 to 28, followed the use of some of the treatments.

TABLE 7.—*Effect of seed treatment with dust fungicides on emergence of 9 varieties of sorghum grown from seed planted April 29, 1937, in a greenhouse maintained at a temperature of 24° C., but ranging at times from 16° to 35°*

Seed treatment [1]	Emergence of —										Increase in emergence following treatment	
	Spur feterita	Sharon kafir	Club	Chiltex	Dwarf Yellow milo	Dwarf hegari	Darso	Sorgo: Sumac	Sorgo: Kansas Orange	All varieties	Absolute	Relative
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
None	4	40	59	52	37	20	74	25	42	38	-----	-----
New Improved Semesan Jr	30	50	82	81	56	26	81	41	59	57	19	50.0
Merko	6	38	69	70	41	30	81	31	61	47	9	23.7
Barbak 111	8	41	79	70	38	38	77	23	61	48	10	26.3
Barbak 36-32-B	12	49	90	76	40	46	76	20	58	54	16	42.1
Copper carbonate	26	64	93	86	55	59	83	44	63	64	26	68.4
Basic copper sulfate	19	66	88	86	55	58	79	38	58	61	23	60.5
Cuprous oxide	17	65	85	85	52	43	79	42	57	58	20	52.6
Ceresan	21	66	89	86	66	55	81	61	68	66	28	73.7
New Improved Ceresan [2]	12	57	80	84	54	39	81	33	53	55	17	44.7
Average of treated seed	16.8	56.1	83.9	80.4	51.8	43.8	79.8	38.0	59.8	56.1	18.7	49.1

[1] All the dust fungicides were applied at the rate of 2 ounces per bushel.
[2] Diluted with talc so as to contain 1 percent of ethyl mercuric phosphate.

The plantings in the field were made May 7, May 20, and June 8. The ranges in soil temperature from planting to emergence in the three field plantings were 7° to 29°, 11° to 32°, and 13° to 35° C., respectively, the corresponding average temperatures being 16.4°, 20.3°, and 24°, respectively. The rainfall during these same periods was 1.59, 2.85, and 1.5 inches, respectively. The average percentages of emergence from seed of each variety treated with each fungicide and sown on each date are shown in table 8, and the averages for each variety for all four plantings, including the one in the greenhouse, are shown in table 9.

As in the last greenhouse planting (table 7), the benefits derived from seed treatment in the field plantings were not so pronounced as they were in some of the preliminary plantings in artificially or naturally infested soil in the laboratory or greenhouse. Among the reasons that may be advanced for this are (1) a lighter rate of application of the fungicides, (2) a longer period between treating and planting the seed, (3) the field soil probably was less heavily infested with fungi deleterious to germination and emergence, and (4) the relatively heavy

TABLE 8.—*Effect of seed treatment with dust fungicides and date of planting on emergence of each of 9 varieties of sorghum in field plots at the Arlington Experiment Farm, 1937*

Seed treatment	Emergence in— Spur feterita	Sharon kafir	Club	Chiltex	Dwarf Yellow milo	Dwarf hegari	Darso	Sorgo: Sumac	Sorgo: Kansas Orange	All varieties	Increase in emergence following treatment: Absolute	Increase in emergence following treatment: Relative
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
PLANTED MAY 7												
None	8	28	41	42	39	21	51	30	44	35	-----	----
New Improved Semesan Jr.	16	34	40	44	42	23	54	34	46	38	3	8.6
Merko	8	37	40	50	35	25	48	29	42	35	0	0
Barbak 111	7	32	57	55	38	25	51	29	44	38	3	8.6
Barbak 30-32-B	12	37	64	61	42	32	56	31	43	42	7	20.0
Copper carbonate	23	52	68	52	44	47	67	35	43	49	14	40.0
Basic copper sulfate	20	53	62	58	44	46	63	35	43	47	12	34.3
Cuprous oxide	17	52	71	62	45	41	57	41	42	48	13	37.1
Ceresan	8	46	53	56	47	23	61	40	39	41	6	17.1
New Improved Ceresan [1]	8	33	46	54	38	24	56	36	42	37	2	5.7
PLANTED MAY 20												
None	19	65	60	61	58	41	72	45	52	53	-----	-----
New Improved Semesan Jr.	36	70	75	68	57	47	79	54	57	60	7	13.2
Merko	23	61	74	64	57	43	75	45	55	55	2	3.8
Barbak 111	16	71	84	73	53	52	80	43	54	58	5	9.4
Barbak 30-32-B	29	65	85	73	50	57	79	50	57	62	9	17.0
Copper carbonate	47	78	81	77	52	67	80	50	61	66	13	24.5
Basic copper sulfate	44	75	84	76	61	66	79	49	50	66	13	24.5
Cuprous oxide	40	74	87	77	50	58	85	48	54	65	12	22.6
Ceresan	35	73	79	75	61	58	85	51	57	64	11	20.8
New Improved Ceresan [1]	23	74	81	76	63	53	74	49	61	62	9	17.0
PLANTED JUNE 8												
None	22	52	60	52	55	45	62	40	42	48	-----	-----
New Improved Semesan Jr.	41	67	67	50	64	58	66	45	49	56	8	16.7
Merko	22	64	71	61	52	54	59	40	54	53	5	10.4
Barbak 111	30	61	76	67	53	55	69	42	54	56	8	16.7
Barbak 30-32-B	27	61	78	61	53	60	61	49	50	56	8	16.7
Copper carbonate	44	65	77	77	46	69	70	46	54	61	13	27.1
Basic copper sulfate	38	62	72	69	42	57	73	40	47	56	8	16.7
Cuprous oxide	40	61	78	68	55	60	63	43	49	57	9	18.8
Ceresan	29	72	62	67	59	50	64	44	47	55	7	14.6
New Improved Ceresan [1]	35	63	68	67	63	46	67	48	50	56	8	16.7

[1] Diluted with talc so as to contain 1 percent of ethyl mercuric phosphate.

rainfall following each field planting may have reduced somewhat the protective and generally beneficial effects of the fungicides. In all 4 plantings, however, all the treatments seemed to cause some increase in emergence. The average increase in the percentage of emergence from treated seed of all varieties above that from untreated seed ranged from 9 to 28 in the greenhouse planting, from 0 to 14 in the first field planting, from 2 to 13 in the second field planting, and from 5 to 13 in the third field planting. In all, there were 278 increases in the percentage of emergence from treated seed, 36 slight decreases, and in 10 cases there was no difference in emergence from treated and untreated seed.

The nine varieties used showed slight differences in their response to seed treatment as measured by the increase in the average percentage of emergence. In Club the extent of this increase was greatest (20.6) and in Dwarf Yellow milo it was the least (4.6). For all nine varieties in the four plantings, emergence from untreated seed averaged 43 percent compared with 54.3 percent from treated seed.

TABLE 9.—*Average percentages of emergence of each of 9 varieties of sorghum from seed lots treated*[1] *with different dust fungicides and planted on successive dates,*[2] *Arlington Experiment Farm, April 29 to June 25, 1937*

Seed treatment	Average[3] emergence of—										Average increase in emergence following treatment	
								Sorgo				
	Spur feterita	Sharon kafir	Club	Chiltex	Dwarf Yellow milo	Dwarf hegari	Darso	Sumac	Kansas Orange	All varieties	Absolute	Relative
	Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
None	13	40	53	52	47	32	65	35	45	43	..	--
New Improved Semesan Jr	31	58	68	61	55	39	70	44	53	53	10	23.3
Merko	15	50	64	61	46	38	66	36	53	48	5	11.6
Barbak 111	15	51	74	66	46	43	69	34	53	50	7	16.3
Barbak 36-32-B	20	53	79	68	51	40	68	40	52	53	10	23.3
Copper carbonate	35	65	80	76	49	61	75	44	55	60	17	39.5
Basic copper sulfate	30	64	77	72	51	57	74	41	52	58	15	34.9
Cuprous oxide	29	63	80	73	53	51	71	41	51	57	14	32.6
Ceresan	23	64	71	71	58	47	73	49	53	57	14	32.6
New Improved Ceresan[4]	20	57	69	70	55	41	70	42	52	53	10	23.3
Average of treatments	24.2	58.3	73.6	68.7	51.6	47.3	70.7	41.6	52.7	54.3	11.3	26.4

[1] Seed was treated April 10 at the rate of 2 ounces per bushel and kept in open glass jars until used.

[2] April 29 (in greenhouse, average temperature 24° C.); May 7, May 20, and June 8 (in field). The rainfall from planting to emergence in the last 3 series was 1.59, 2.85, and 1.5 inches, respectively, and the average temperatures 16.4°, 20.3°, and 24°, respectively.

[3] Each figure below each variety represents the average percentage emergence from 2,100 seeds.

[4] Diluted with talc so that when applied at 2 ounces per bushel, the seed received the proper amount of chemical.

EXPERIMENTS ON SMUT CONTROL

In addition to the beneficial effect on emergence and early stand, a seed treatment, in order to be generally recommended for use on sorghum seed, also should control the kernel smuts caused by *Sphacelotheca sorghi* (Lk.) Clint. and *S. cruenta* (Kuehn) Potter. Therefore, the fungicides in the above studies were used, along with others, in experiments on the control of kernel smut. Since the loose smut caused by *S. cruenta* is less prevalent and more easily controlled than is covered kernel smut, only the latter was used in these experiments.

In the experiments of 1937, spores of covered kernel smut were applied to seed of 4 varieties of sorghum at a spore dosage of 1 to 100. Each of the 4 lots of seed, black with this heavy spore load, was divided into 12 portions. One portion of each was left untreated and each of the others was treated with a different fungicide. Nine of these fungicides were applied as dusts and 2 as liquids. The dusts were applied May 17 at the rate of about 2 ounces per bushel (0.05 gm. of dust per 20 gm. of seed) in clean bottles and thoroughly mixed with the seed by shaking for several minutes. New Improved Ceresan, ordinarily applied at the rate of one-half ounce per bushel, was diluted with 3 parts by weight of talc so that the seed, when dusted at the rate of 2 ounces per bushel, would receive the proper quantity of the ethyl mercuric phosphate.

The "M. E. Chlorine" solution of sodium hypochlorite was diluted with 50 parts of water according to directions given on the label. The seed was immersed in this solution containing about 0.15 percent of sodium hypochlorite for 15 minutes and then drained and dried. Hychlorite, the other brand of sodium hypochlorite, was used as a solution containing 1 percent of sodium hypochlorite in which the seed was immersed for one-half hour after which it was rinsed and dried.

The seed was planted by hand June 8 in 33-foot rows at the rate of about 250 seeds per row. The soil was wet and heavy, and 2.3 inches of rain fell before the seedlings emerged. The data on smut infection are given in table 10.

The outstanding feature of the results is the failure of any of the treatments to eliminate smut infection in all four varieties consistently and effectively. The number of smutted heads from untreated seed in the four varieties ranged from 61.2 to 73 percent. Copper carbonate, Ceresan, and Merko were the only treatments that reduced infection in any variety to 5 percent or less, and only copper

TABLE 10.—*Covered kernel smut (Sphacelotheca sorghi) in sorghum grown from seed smutted at a spore dosage of 1 to 100, treated*[1] *May 17 with different fungicides, and planted June 8, 1937, at the Arlington Experiment Farm together with untreated smutty seed*

Treatment	Smutted plants[2] in—						Smutted heads in—						
	Sharon kafir	Sorgo		All 3 varieties			Sharon kafir	Black Spanish broomcorn	Sorgo		All 4 varieties		
		Kansas Orange	Sumac	Total	Smutted				Kansas Orange	Sumac	Total	Smutted	
	Pct.	*Pct.*	*Pct.*	*No.*	*No.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*No.*	*No.*	*Pct.*
None	57.4	69.5	44.5	375	212	56.5	64.9	73.0	72.9	61.2	1,097	663	60.4
New Improved Semesan Jr	5.6	30.4	19.7	397	78	19.6	10.9	33.1	31.9	20.0	910	258	28.4
Merko	3.7	20.6	19.7	392	61	15.6	5.0	21.2	22.4	30.7	964	219	22.7
Barbak 111	73.1	70.6	56.5	361	238	65.9	80.6	79.7	61.6	72.1	1,120	821	73.3
Barbak 36-32-B	21.8	35.6	21.0	356	96	27.0	28.3	35.2	41.0	34.8	856	305	35.6
Copper carbonate	9.8	0	4.1	379	18	4.7	12.6	39.8	0	4.0	971	138	14.2
Basic copper sulfate	13.9	10.5	6.6	385	39	10.1	14.1	29.2	12.9	7.0	886	156	17.6
Cuprous oxide	12.3	15.4	11.7	374	49	13.1	14.3	28.3	15.0	29.0	957	200	20.9
Ceresan	23.5	31.9	2.1	364	65	17.9	28.2	22.7	32.6	3.0	882	193	21.9
New Improved Ceresan[3]	46.4	29.4	11.4	321	92	28.7	53.9	37.0	31.8	14.4	875	287	32.8
M. E. Chlorine[4]	28.7	30.4	27.3	356	101	28.4	32.5	46.1	29.0	37.3	977	374	38.3
Sodium hypochlorite[5]	45.3	26.8	29.5	370	122	33.0	52.2	11.4	25.1	35.3	971	260	26.8

[1] All the dusts were applied at the rate of 2 ounces per bushel.
[2] Because of lodging, it was not possible to get accurate plant counts on the broomcorn.
[3] Diluted with 3 parts of talc (by weight).
[4] Seed soaked 15 minutes in a 1 to 50 solution, drained, and dried.
[5] Seed soaked in a 1-percent solution for ½ hour, washed in water, and dried.

carbonate effected perfect control in any one variety. The results with these three materials in the different varieties, however, were highly inconsistent. For example, copper carbonate effected perfect control in Kansas Orange sorgo but allowed 39.8 percent infection in the broomcorn, although the controls in both varieties showed about the same degree of infection. The percentages of smutted heads from seed treated with Merko ranged from 5 to 30.7 and with Ceresan from 3 to 32.6. Basic copper sulfate reduced infection in the broomcorn to 29.2 percent, and in Sumac sorgo to only 7 percent. Seed treated with Barbak 111, with one exception, produced a higher percentage of smutted heads than did untreated seed. The five best treatments in the order of their average effectiveness were: Copper carbonate, basic copper sulfate, cuprous oxide, Ceresan, and Merko.

To compare the percentage of infection by covered kernel smut based on the number of smutted heads with that based on the number of smutted plants, the total number of plants and the number of infected plants from 3 lots of treated and untreated seed were counted. In 35 individual comparisons the percentage of smutted heads exceeded the corresponding percentage of smutted plants 31 times by amounts ranging from 0.2 to 17.6. In 4 instances the percentage of smutted plants exceeded that of smutted heads by amounts ranging from 0.1 to 9. The average percentages of smutted plants and smutted heads from untreated seed were 57.1 and 66.3 percent, respectively, while from treated seed they were 24.3 and 27.9 percent, respectively. The differences in the data obtained from head counts and plant counts were not considered sufficiently large to justify the additional time and effort involved in the latter method of taking data on smut infection. In subsequent field experiments, therefore, the data on smut infection were based on the percentage of infected heads.

In the experiments in 1938, five of the fungicides used in 1937 were omitted and six others were included. The seed was smutted at a spore dosage of 1 to 100 as in 1937, and, with the exception of New Improved Ceresan, the dusts were applied at the rate of 3 gm. to 1,000 gm. of seed, which is at the rate of nearly 3 ounces per bushel. The formaldehyde treatment consisted of a half-hour soak in a 1 to 240 (0.4-percent) solution. The sodium hypochlorite was applied by immersing the seed in a 1-percent solution for a half hour. The chlorine treatment consisted of exposing the seed for 1 hour in a gas-tight container in which the air contained 10 percent by volume of chlorine gas (*9*). The actual volume of the chlorine gas used was equal to 40 percent of the volume of seed in the container.

The effect of the fungicides on emergence was determined by planting 300 seeds of each treated and untreated lot in a greenhouse bench. Plantings were made in the field, June 2 and June 13. The data on smut control from these two series were substantially alike and, therefore, were averaged and, together with the data on emergence, are given in table 11.

TABLE 11.—*Covered kernel smut (Sphacelotheca sorghi) in sorghum grown from smutted seed, treated May 16* [1] *with different fungicides, and planted in 44-foot rows at the Arlington Experiment Farm, June 2 and June 13, 1938, together with untreated smutty seed*

Seed treatment	Average emergence	Smutted heads in— Sharon kafir	Smutted heads in— Scarborough broomcorn	Smutted heads in— Leoti sorgo	Heads in all varieties Total	Heads in all varieties Smutted	
	Pct.	*Pct.*	*Pct.*	*Pct.*	*No.*	*No.*	*Pct.*
None (untreated check)	52	56.9	61.1	76.4	1,003	651	64.9
New Improved Ceresan [2]	61	1.8	7.0	0	332	13	3.9
Merko	48	21.7	31.0	10.1	395	87	22.0
Barbak C	55	17.1	54.4	40.7	464	205	44.2
Copper carbonate	52	9.8	49.5	15.4	395	129	32.7
Basic copper sulfate	57	4.0	43.1	13.5	448	120	26.8
Cuprous oxide	57	12.2	24.5	33.0	476	123	25.8
Sulfur	52	42.7	32.0	10.0	496	142	28.6
Sanoseed	54	60.0	62.3	67.1	564	358	63.5
Vasco 4	49	51.5	61.1	41.8	644	348	54.0
Copper oxychloride	58	43.6	53.4	35.4	611	287	47.0
Formaldehyde	38	0	0	0	453	0	0
Sodium hypochlorite	44	0	1.1	0	574	3	.5
Chlorine gas [3]	49	1.4	0	0	466	1	.2

[1] The liquid treatments were applied the day before planting, formaldehyde as a 1 to 240 (0.4-percent) solution for 1/2 hour, and sodium hypochlorite as a 4-percent solution for 1/2 hour.
[2] Applied at the rate of 1/2 ounce per bushel; all other dusts at 3 ounces per bushel.
[3] Seed exposed to 10 percent chlorine gas for 1 hour.

With the exception of formaldehyde, New Improved Ceresan, and possibly sodium hypochlorite, none of the fungicides significantly affected emergence. As in 1937, the dust fungicides, with one exception, were relatively ineffective in controlling smut. New Improved Ceresan reduced the average percentage of smutted heads in the three varieties to 3.9 compared with 64.9 for no treatment, and with 22 to 63.5 for the other nine dusts. Next in the order of their average effectiveness were Merko, cuprous oxide, basic copper sulfate, sulfur, and copper carbonate. Sanoseed, copper oxychloride, Vasco 4, and Barbak C were especially ineffective. Formaldehyde eliminated all smut in all three varieties, while sodium hypochlorite permitted 1.1 percent in broomcorn and chlorine gas 1.4 percent in kafir.

No entirely satisfactory explanation can be offered for the poor smut control obtained in 2 successive years with dust fungicides, some of which had given excellent results in experiments on the control of stinking smut of wheat at the Arlington Experiment Farm (*7*) over a period of several years. The heavy spore load on the seed and the soil conditions after planting being highly conducive to smut infection doubtless subjected the fungicides to an unusually severe test, but not any more severe, it is thought, than did the conditions obtaining in the experiments with bunt in which satisfactory control was obtained when infection in the checks was as high as 90 percent.

In table 11, it is noticeable that infection from dusted seed was higher in the broomcorn than in other sorghums in 7 out of 10 cases. This, it was thought, may have been partly due to the fact that many of the seeds of this variety retained their glumes and thus made smut control with dusts more uncertain (*2*, *5*).

To determine to what extent glumes on the seed appreciably affect the incidence of smut or its control in sorghum, the following experiment was carried out in the greenhouse in the winter of 1938–39. Each of four remnant seed lots of Leoti sorgo from the previous season's experiments was carefully separated into two portions, one consisting of seed with adherent glumes and the other without glumes. Three of these lots had been inoculated and treated as previously described, and the other was the inoculated untreated check. Six hundred seeds of each lot, half of them without glumes, were planted without further treatment in soil 50 percent saturated and maintained at 20° C. Five days after emergence the seedlings were transplanted to the greenhouse bench where they were grown to maturity, at which stage the data on smut infection were taken. A similar experiment with seed of Scarborough broomcorn, used in the 1939 experiments, was carried out in the field the following spring. The data from these two experiments are given in table 12.

TABLE 12.—*Infection by covered kernel smut and its control in sorghum as affected by the retention of glumes on the seed*

Seed treatment	Glumes	Plants [1] of Leoti sorgo—			Heads [2] of Scarborough broomcorn	
		Emerged	Matured	Smutted	Total	Smutted
		Pct.	*No.*	*Pct.*	*No.*	*Pct.*
None	On	74	220	48.2	264	20.6
Do	Off	24	72	93.8	242	50.0
New Improved Ceresan	On	77	230	0	236	0
Do	Off	44	44	0	276	0
Copper carbonate	On	54	162	0	220	4.6
Do	Off	33	99	0	216	0
Cuprous oxide	On	56	168	3.6	249	10.0
Do	Off	35	104	0	238	0

[1] Grown in the greenhouse under controlled conditions, highly favorable for smut development.
[2] Grown in the field. Soil was relatively dry and warm from planting to emergence.

The results indicate that seeds free of glumes, when inoculated with spores of covered smut, produce a more heavily smutted crop than do seeds with adherent glumes. There also is some indication that the presence of glumes on the seeds renders smut control more uncertain. In three of four comparisons, treatment of the glumed seeds with copper dusts failed to eliminate all of the smut, while the treated glumeless seeds produced no smutted plants, even though the untreated glumeless seeds produced plants with almost twice as much infection as did untreated glumed seeds. In Leoti, the average emergence from glumed seeds was almost twice that from glumeless seeds.

An attempt was made also to determine the possible effect of excessive or deficient soil moisture on the control of smut by dust fungicides. Three separate lots of Keyport silt loam were adjusted to 30, 50, and 70 percent saturation, respectively. Seed of Leoti sorgo, inoculated with smut spores at a spore dosage of 1 to 100 and dusted with copper carbonate or cuprous oxide at 3 ounces per bushel or New Improved Ceresan at three-fourths of an ounce per bushel, was planted in each of the three lots of soil. A temperature of 20° C. was maintained during emergence. The moisture content of the soils was kept as nearly constant as possible for several weeks after the plants had emerged. The data on smut infection and control are given in table 13.

TABLE 13.—*Development and control of covered smut in Leoti sorgo planted in the greenhouse in soils adjusted to 3 different percentages of saturation*

Soil saturation (percent)	Infected plants from—					Relative control [1]
	Untreated seed	Seed treated with—			All treated seed	
		Copper carbonate	Cuprous oxide	New Improved Ceresan		
	Percent	*Percent*	*Percent*	*Percent*	*Percent*	*Percent*
30	26.8	1.0	3.6	0	1.4	94.8
50	81.6	2.1	0	0	.7	99.1
70	5.6	1.0	1.1	0	.7	87.5

[1] Computed according to the formula:

$$100-\left(\frac{\text{Percentage smutted plants from treated seed}}{\text{Percentage smutted plants from untreated seed}}\times 100\right)$$

The infection percentages, 26.3, 81.6, and 5.6 in soil 30, 50, and 70 percent saturated, respectively, show a very pronounced relation between relative soil moisture and infection by smut in the plants from untreated seed. The results in the dry soil are in agreement with the general conclusions of Melchers and Hansing (*12*) that at Manhattan "low soil moisture (i.e., below 8 or 10 percent on the dry basis) reduces the amount of infection." Soil from Manhattan was found (*8*) to have a water-holding capacity of about 40 percent, and therefore a moisture content of 10 percent would be equivalent to 25 percent saturation. Reed and Faris (*14*), using sand, obtained the highest infection percentages at 10-percent saturation. Results in sand and in soil, however, are not entirely comparable, for although the water-holding capacity of sand is usually lower than that of soil, the water it contains is more available. Although the relation between soil moisture and smut control was not very pronounced, there is some indication in these data that control is favored by a medium quantity of soil moisture and hindered by excessive and possibly also deficient soil moisture.

Experiments on smut control in 1939 were limited to studies involving 3 spore dosages and 6 dust fungicides on seed of 3 varieties. New Improved Ceresan was applied undiluted at the recommended rate of one-half ounce per bushel. The 5 other dusts were applied by the excess method.[5] The seed was treated May 17 and planted May 23 at the rate of 500 seeds per 44-foot row. The soil at planting time was unusually dry, and no rain fell until after emergence, which, as a result, was somewhat uneven. The temperature during the period of emergence ranged from 21° to 32° C., with a mean of about 26°. The average stand from seed treated with the copper dusts was increased 12.5 percent, while that from seed treated with the other 3 dusts was not appreciably affected, compared with emergence from untreated seed. The data on smut infection taken in August and September are given in table 14.

TABLE 14.—*Occurrence and control of covered kernel smut in sorghum as affected by spore dosage and seed treatment, Arlington Experiment Farm, 1939*

Seed treatment	Spore dosage	Smutted heads in—			Heads in all varieties	
		Sharon kafir	Scarborough broomcorn	Leoti sorgo	Total	Smutted
		Percent	*Percent*	*Percent*	*Number*	*Percent*
None	1-100	14.3	22.0	35.4	481	23.1
	1-300	18.1	17.9	21.4	529	19.3
	1-600	15.3	21.1	15.4	544	17.3
New Improved Ceresan[a]	1-100	0	0	0	422	0
	1-300	0	0	0	512	0
	1-600	0	0	0	552	0
Copper carbonate	1-100	0	0	0	453	0
	1-300	0	0	0	631	0
	1-600	0	0	0	666	0
Basic copper sulfate	1-100	0	0	0	509	0
	1-300	0	0	0	631	0
	1-600	0	0	0	603	0
Cuprous oxide	1-100	0	0	0	463	0
	1-300	0	0	0	631	0
	1-600	0	0	0	625	0
Sulfur	1-100	0	0	0	447	0
	1-300	0	0	0	451	0
	1-600	0	0	0	567	0
Merko	1-100	0	2.2	1.3	466	1.3
	1-300	0	1.2	.7	458	.7
	1-600	6	1.4	0	605	.7

[a] Applied at the rate of ½ ounce per lbushel; the remaining dusts were applied by the excess method.

The excellent control of smut by the three copper dusts and Merko contrasts strongly with the results from these materials in the 2 previous years. This may possibly be attributed to heavier applications of the dust fungicides and to conditions after planting being less conducive to smut infection. Sulfur, although apparently ineffective in promoting better stands in this and previous experiments, was surprisingly effective in smut control. This is in contrast with Barbak 111 and

[5] In laboratory tests, Sharon kafir, dusted by the excess method, retained copper carbonate, cuprous oxide, and basic copper sulfate in amounts equal to 8.2, 10.5, and 7.9 ounces per bushel, respectively.

several other dusts that were effective in improving emergence in the 1937 and 1938 experiments, but very ineffective in controlling smut.

Decreasing the spore dosage in this experiment did not cause a proportionate decrease in the percentage of infection. In fact, under the conditions of this experiment, which evidently were not highly conducive to infection, there seemed to be little consistent relation between spore dosage within the range used and occurrence or control of smut.

Because of the low percentage of smutted heads from untreated seed, it seemed desirable to repeat the above experiment with seed treated with certain of these dusts at different rates and planted under conditions more favorable for severe smut infection. This was attempted both in the greenhouse and in the field in 1940. The soil used in the greenhouse experiments was infested with the usual soil-borne organisms. In the first experiment Sharon kafir seed was dusted at a spore dosage of 1 to 100 with viable spores of covered smut from the 1939 crop. Separate portions were treated with New Improved Ceresan at ½, 1, and 1½ ounces per bushel, and with copper carbonate or basic copper sulfate at 2, 4, and 8 ounces per bushel. Any excess fungicidal dust at the 8-ounce-per-bushel rate was removed by sieving the seed.

The seed was planted in the greenhouse bench 1½ inches deep in soil about 50 percent saturated. For each rate of application of each dust there were planted 10 replications of 100 seeds each. Every fourth row was planted to untreated seed. The soil was covered with canvas and maintained at a temperature of 18° to 21° C. until the seedlings were about to emerge. After data on emergence had been obtained, the plants were thinned sufficiently to permit normal growth and heading. The data on emergence and smut control are given in table 15.

TABLE 15.—*Effect of seed treatment with 3 dust fungicides on emergence and smut control in Sharon kafir grown in the greenhouse from smutted seed, treated at each of 3 rates of application, 1940*

Fungicide	Rate per bushel	Total emergence	Increase in emergence following treatment [1]		Plants matured	
			Absolute	Relative	Total	Smutted
	Ounces	*Percent*	*Percent*	*Percent*	*Number*	*Percent*
None (smutty check)		31.7			100	35
New Improved Ceresan	½	48.1	18.4	62.0	112	0
Do	1	58.0	28.3	95.3	113	0
Do	1½	63.4	33.7	[2] 113.5	117	0
None (smutty check)		27.0			116	40
Copper carbonate	2	66.7	36.4	120.1	118	0
Do	4	73.6	43.3	142.9	111	0
Do	8	77.9	47.6	[2] 157.1	117	0
None (smutty check)		32.9			107	31
Basic copper sulfate	2	73.0	41.0	128.1	115	0
Do	4	80.7	48.7	[2] 152.2	112	0
Do	8	77.6	45.6	142.5	112	0
None (smutty check)		31.1			97	30

[1] Compared with average of the 2 nearest checks.
[2] Significant increase over lowest rate of application.

In the heavily infested greenhouse soil, treatment of the seed in every case was followed by pronounced increases in the percentage of emergence, compared with that from untreated seed. Emergence percentages from seed treated at the rate of 1½ ounces of New Improved Ceresan, 8 ounces of copper carbonate, or 4 ounces of basic copper sulfate per bushel were significantly greater than those from seed treated at the lowest rates with each of these respective fungicides, as determined by the pairing method (*10*).

Smut, which ranged from 30 to 40 percent in the checks, was controlled perfectly by all three fungicides at all rates of application used. Therefore, it seems that for the purpose of controlling smut under the conditions of this experiment the application of these dusts at rates heavier than those generally recommended for that purpose was of no advantage.

In a second experiment, which was carried out both in the field and greenhouse in the spring of 1940, seed of Sharon kafir and Leoti sorgo was dusted with spores of covered kernel smut at spore dosages of 1 to 100, 1 to 300, and 1 to 600, and on May 1 separate portions of each lot were treated with six fungicidal dusts. New Improved Ceresan was applied at the rate of ½, 1, and 1½ ounces per bushel, and the five other dusts at 2, 4, and 8 ounces per bushel. A formaldehyde treatment with a 1 to 240 solution for one-half hour also was included.

The effect of the rate of application of the 6 dusts on emergence in unsterilized naturally infested soil was studied by planting in the greenhouse May 8, 300 seeds of each variety, treated with each dust at each of the 3 rates of application. Later 1,500 seeds of each lot were planted in the field at Arlington Farm, and 600 each at Hays, Kans., and at Dalhart, Tex.,[5] for studies on emergence and also on smut control.

The temperature during emergence in the greenhouse ranged from 15° to 35° C. and averaged 25.6°. The soil moisture was adjusted to about 50-percent saturation. The soil in the bench had been recently replaced and therefore was not so badly infested as that used in previous greenhouse experiments. As a result of these favorable conditions, emergence was considerably better than it was in the field planting at Arlington Farm, where the average temperature was 20° and the rainfall 2.5 inches during the period of emergence. At Hays, better moisture and temperature conditions resulted in emergence percentages that compared favorably with those obtained in the greenhouse. At Dalhart, extreme drought conditions after planting inhibited emergence to such an extent that no data of value could be obtained.

Results on smut control were not obtained at Hays or Dalhart because extreme drought conditions prevented heading. The data on smut control obtained at Arlington Farm are given in table 16, together with the data on emergence in the greenhouse and in the field. Because the different spore dosages seemed to have no effect on emergence, these results from the three lots of seed are combined.

TABLE 16.—*Emergence and smut control in 2 varieties of sorghum grown from smut-inoculated seed treated with different fungicides at 3 rates of application, 1940*

Fungicide	Rate per bushel	Emergence of— Sharon kafir: Greenhouse	Sharon kafir: Field: Arlington	Sharon kafir: Field: Hays	Leoti sorgo: Greenhouse	Leoti sorgo: Field: Arlington	Leoti sorgo: Field: Hays	Smut-infected heads of— Sharon kafir at spore dosage of— 1 to 100	Sharon kafir: 1 to 300	Sharon kafir: 1 to 600	Leoti sorgo at spore dosage of— 1 to 100	Leoti sorgo: 1 to 300	Leoti sorgo: 1 to 600
	Ounces	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
None		88	56	71	82	44	59	28.6	17.7	16.7	14.3	23.8	21.6
New Improved Ceresan	½	87	66	88	82	55	80	0	0	0	0	0	3.2
	1	86	65	87	70	42	67	0	0	0	0	0	0
	1½	80	69	83	59	35	60	0	0	0	0	0	0
Copper carbonate	2	83	65	86	86	51	74	0	0	0	0	0	0
	4	79	69	85	82	55	77	0	0	1.3	1.7	0	0
	8	84	73	82	73	42	74	0	0	0	0	0	3.1
Basic copper sulfate	2	79	76	84	83	43	78	0	0	0	.9	.8	0
	4	86	79	88	85	44	77	0	0	0	0	0	0
	8	74	63	79	70	39	75	0	0	0	0	0	0
Cuprous oxide	2	82	77	84	82	53	77	0	0	0	0	.9	6.1
	4	79	70	78	76	46	80	0	0	0	0	.8	0
	8	81	64	80	74	41	77	0	0	0	0	0	0
Sulfur	2	79	61	66	81	39	56	0	0	0	0	0	0
	4	77	58	65	83	46	64	0	0	0	0	0	0
	8	85	55	61	78	43	61	0	0	0	0	0	0
Merko	2	76	50	66	78	41	63	28.2	4.0	0	11.9	5.3	19.8
	4	82	58	65	76	38	64	32.0	10.0	7.5	17.8	4.2	5.6
	8	80	57	68	81	41	66	24.7	10.0	0	6.5	.7	0
Formaldehyde		66	46	40	84	36	61	0	0	0	1.0	.8	0
None		89	58		83	41		14.5	19.4	4.6	4.5	11.1	15.7

On the whole, in these later plantings better emergence and smut control did not follow consistently the use of dust applications heavier than those usually recommended. In Leoti, emergence from seed treated with New Improved Ceresan at three times the recommended rate averaged 29 percent less than from seed treated at the standard rate, while in Sharon kafir the average reduction was

[5] The work at Hays, Kans., and Dalhart, Tex., was done by A. F. Swanson and B. F. Barnes, respectively. Their generous assistance is gratefully acknowledged.

only 3.7 percent. There seemed to be no consistently significant differences in either variety between the percentages of emergence from seed treated with the other dusts at 2, 4, and 8 ounces per bushel. In Leoti four of the dusts effected slightly better smut control when they were applied at the heavier rates, but the opposite result was obtained with copper carbonate. In Sharon kafir, smut control apparently was not affected by the rate of application of any of the fungicides. The data on smut infection and control, however, were erratic, probably because of lack of uniformity in soil conditions in the plot of ground used. Infection in the checks ranged from only 4.6 to 28.6 percent in Sharon and from 1.5 to 23.8 percent in Leoti. Paradoxically, the lowest infection in the Leoti controls was from seed inoculated at the heaviest spore dosage.

Although the best smut control was obtained with sulfur, its ineffectiveness as a seed protectant places it among the less preferred fungicides for sorghum seed

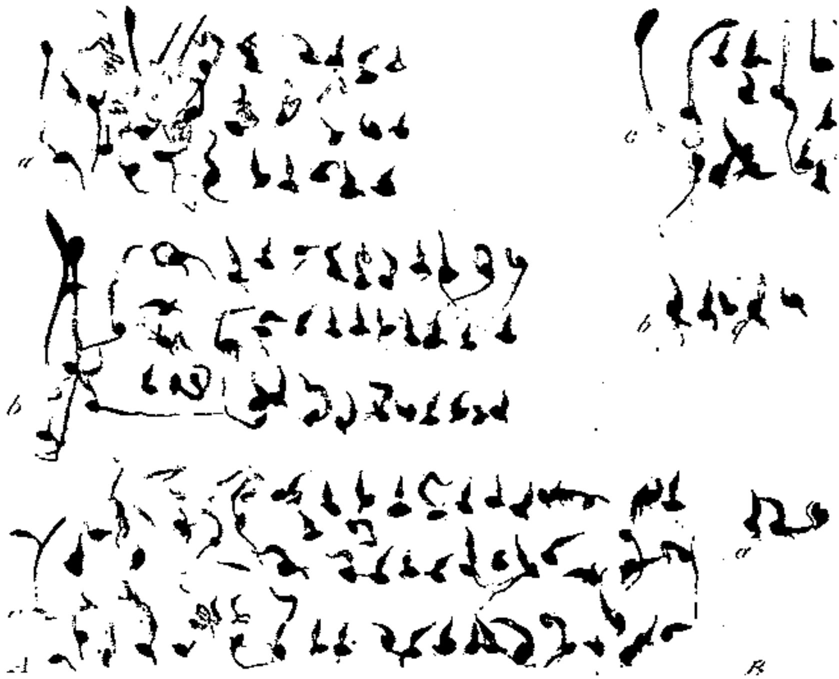

FIGURE 2.—Mercury injury to seedlings of *A*, Leoti sorgo and *B*, Sharon kafir grown in soil from seeds treated with New Improved Ceresan at *a*, ½; *b*, 1; and *c*, 1½ ounces per bushel 30 days before planting.

treatment. Merko, which apparently had deteriorated with age, failed to control smut satisfactorily except in three seed lots receiving applications of 8 ounces per bushel. Formaldehyde eliminated smut in four out of six seed lots, but it also reduced emergence in four out of six trials.

In an additional experiment to study the effect of delayed planting after treatment with New Improved Ceresan on emergence and seedling injury 300 seeds of each lot, treated with this chemical, were planted in sterilized soil, 2, 5, 15, 30, and 45 days after treatment. The results, given in table 17, indicate that injury to the seed following treatment with this material depends more on the variety grown and on the rate of application than on the length of time between treating and planting. When seed was treated at the recommended rate of one-half ounce per bushel and stored for 30 days, emergence was improved 5.9 percent in Sharon kafir but reduced 5.3 percent in Leoti, and 1.1 percent of the Sharon kafir and 11.7 percent of the Leoti sorgo seedlings showed mercury injury. When the dust was applied at 2 and 3 times the recommended rate, emergence was improved 9.4 and 2.4 percent, respectively, in kafir but reduced 26.7 and 30.7 percent, respectively, in sorgo. Mercury injury to the sorgo seedlings also was much greater than to the kafir seedlings (fig. 2). Doubling or trebling the period between treating and planting, however, was not always followed by an increase in the amount of mercury injury, but frequently by a decrease. Thus, emergence in Sharon kafir was not greatly affected by the rate of application or the period of storage, but in Leoti both these factors seemed to have a pronounced effect.

TABLE 17.—*Emergence and mercury-injured seedlings of Sharon kafir and Leoti sorgo from seed treated at 3 rates of application with New Improved Ceresan and then stored for periods of 2, 5, 15, 30, and 45 days before planting*

Variety	Rate per bushel	Emergence from seed after storage for—					Deformed seedlings[1] from treated seed stored—					
		2 days	5 days	15 days	30 days	45 days	15 days		30 days		45 days	
	Ounces	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*	*No.*	*Pct.*
Sharon kafir	0	92	81	78	85	84	0	0	0	0	0	0
	½	94	94	91	90	94	6	2.2	3	1.1	4	1.4
	1	93	94	90	93	93	9	3.3	5	1.8	6	2.2
	1½	91	91	89	87	88	18	6.7	13	5.0	15	5.7
Leoti sorgo	0	77	69	67	75	78	0	0	0	0	0	0
	½	77	74	87	71	70	21	8.0	25	11.7	40	19.0
	1	75	65	64	55	57	65	33.9	39	23.6	60	35.1
	1½	72	62	55	52	61	88	53.3	57	30.5	50	27.3

[1] Due to injury by mercury.

Seed-treatment experiments in 1941 were limited to testing the efficiency of Spergon, a recently developed, nonmetallic organic compound, in comparison with New Improved Ceresan and copper carbonate. This material, consisting of 99 percent tetrachloro-para-benzoquinone, is a yellow powder of extreme fineness, which adheres readily to the seed. Felix (*8*) has reported excellent results from its use on peas and cottonseed.

In May 1941, seed of Sharon kafir was inoculated with spores of covered kernel smut at a spore dosage of 1 to 100, and separate portions of the smutty seed were treated with New Improved Ceresan at one-half ounce per bushel and with copper carbonate and with Spergon at 3 ounces per bushel. The seed was planted in June in 33-foot rows at Beltsville, Md., and, through the cooperation of A. F. Swanson, also at Hays, Kans. Seed of kafir and feterita, treated as above, was also planted in the greenhouse at Beltsville where the average temperature was about 20° C. during the period of germination. The data on emergence in the greenhouse and the data on smut control in the field are given in table 18.

TABLE 18.—*The effect of 3 seed disinfectants on emergence and covered kernel smut control in sorghum in 1941*

Seed disinfectant	Rate per bushel	Emergence in—		Smutted heads at—	
		Feterita	Kafir	Beltsville, Md.	Hays, Kans.
	Ounces	*Percent*	*Percent*	*Percent*	*Percent*
New Improved Ceresan	½	62	87	0	0
Spergon	3	75	88	0	0
Copper carbonate	3	62	87	0	1
Check		44	80	55.0	37.0

The beneficial effect of Spergon on emergence together with its excellent control of covered kernel smut appear to justify placing it among the dust fungicides suitable for treating sorghum seed.[7]

[7] In experiments at seven stations in 1942 in which smut in the controls ranged from 7.8 to 43.4 percent Spergon again improved emergence and controlled smut in Sharon kafir when applied to heavily smutted seed at 3, 1½, and ¾ ounces per bushel. Similar results were obtained also with tetramethy-thiuramdisulfide, ferricdimethyl-dithiocarbamate, and morpholine-thiuramdisulfide. Mercapto-benzothiazole was effective when applied at 3 ounces per bushel. Sanoseed (2.2 percent ethanol mercuric chloride) was relatively ineffective. LEUKEL, R. W. NEW FUNGICIDES AND REDUCED FUNGICIDE DOSES FOR THE CONTROL OF KERNEL SMUT OF SORGHUM. (Phytopath. Note) Phytopath. 32: 1091-1093. 1942.

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U. S. GOVERNMENT PRINTING OFFICE: 1943

For sale by the Superintendent of Documents, U. S. Government Printing Office
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