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MANHATTAN, KANSAS

THE CONTROL OF SORGHUM KERNEL SMUT AND THE EFFECT OF SEED TREATMENTS ON VITALITY OF SORGHUM SEED

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SUMMARY

1. The dry formaldehyde method of treating sorghum seed for smut does not give as satisfactory smut control as the standard formaldehyde treatment. Furthermore, injury to seed often is greater in the former than in the latter method.

2. The injury to the seed by the dry formaldehyde method was found to be proportional to the dosage of formaldehyde used and not to the time the seed was covered after treatment.

3. In formaldehyde soaking treatments satisfactory smut control was obtained when the strength of the solution was increased and the length of treatments decreased. Seed injury, however, was somewhat increased. Soaking the seed in a 1-240 solution for 30 minutes gave practically as good smut control as soaking for one hour. Storage of seed treated with strong formaldehyde seems to be unsafe.

4. Dry heat treatments did not control sorghum kernel smut except when the temperature was so high as to injure the germinability of the seed, or when the treatment was supplemented by the standard formaldehyde treatment.

5. Treatment with copper sulphate solutions gave nearly as good smut control as treatment with formaldehyde and slightly less seed injury than formaldehyde.

6. A number of commercial chemical compounds which are used as solutions were found to give reasonably good smut control and very little seed injury. Of these Chlorophol, Corona No. 620, Semesan, Pythal, Kalimat, and Uspulun gave good results.

7. Dust treatments are the most promising of the new treatments for the control of covered kernel smut. of sorghums.

8. Copper carbonate dust applied at the rate of 2 to 4 ounces per bushel of seed, depending upon the copper content, has given excellent smut control in experimental and demonstration plantings. No appreciable seed injury has resulted from the use of this treatment. This method is being recommended and extensively used at the present time in Kansas.

9. Dehydrated copper sulphate, Dosch copper-lime, flowers of sulphur, Corona Nos. 40S and 640, gave excellent results. Sulphur dust of various makes seem to be nearly as promising as copper carbonate for sorghum seed treatment and have the advantage of costing considerably less.

10. In all treatments the amount of seed injury has been found to be dependent in a large measure on the physical condition of the seed. Scarred, cracked, dull or dirty, and immature seed are often injured by relatively mild treatments, while good, sound, clean, well-matured sorghum seed is seldom injured by more severe treatment.

TABLE OF CONTENTS

THE CONTROL OF SORGHUM KERNEL SMUT AND THE EFFECT OF SEED TREATMENTS ON VITALITY OF SORGHUM SEED [1]

C. O. Johnston and L. E. Melchers [2]

INTRODUCTION

The sorghum crop is of tremendous importance in the southwestern Great Plains where insufficient rainfall and other climatological factors render the production of corn uncertain. Southwestern Kansas, western Oklahoma, and adjoining portions of Texas, New Mexico and Colorado include more than 90 per cent of the acreage and produce more than 90 per cent of all grain sorghums grown in the United States. These same states produce about' the same per cent of broomcorn and of the sorghums used for forage and silage. Kansas is the third largest sorghum-producing state in the United States, being exceeded only by Texas and Oklahoma. More than one-fourth of all grain sorghums produced in the five-year period, 1919 to 1924, inclusive, was grown in Kansas.

The average annual acreage of sorghums in Kansas is about 2,367,000 acres, producing an average annual yield of 25,000.000 bushels of grain, 5,000,000 tons of cured forage, 750,000 tons of silage, 5,000,000 brooms, and 274,000 gallons of sirup. The average annual value of the crop is about $37,000,000, which is about one-fourth the average annual return from wheat for the five-year period, 1920 to 1924 inclusive. Kafir alone is the fourth most important grain crop in the state from the standpoint of cash value.

The western half of Kansas produces most of the grain sorghum in the state and a large proportion of the forage and silage sorghums, although considerable sorghum is grown in eastern Kansas both for forage and grain. The importance of the sorghum crop, which is brought out in the above discussion, demands that the best methods of production be employed.

One of the principal sources of loss in the production of sorghums is disease. Fortunately sorghums are affected by fewer diseases in this state than are wheat and corn. This may be due to natural

1. Contribution No. 252 from the Department of Botany, Kansas Agricultural Experiment Station, in coöperation with the Office of Cereal Crops and Diseases, United States Department of Agriculture.

2. C. O. Johnston is assistant pathologist, Office of Cereal Crops and Diseases, United States Department of Agriculture, and L. E. Melchers is agent, Office of Cereal Corps and Diseases, United States Department of Agriculture, and plant pathologist, Kansas Agricultural Experiment Station.

resistance, to the semiarid conditions under which the crop is grown, or to a combination of these two factors. The two diseases which cause the greatest loss in Kansas are kernel smut, *Sphacelotheca sorghi* (Lk.) Clint., and head smut, *Sorosporium reilianum* (Kühn) McAlp. The latter is of relatively small importance since it occurs only in very slight amounts in certain varieties. Red Amber sorgo, in the western half of the state, has head smut more frequently than any other variety, although the per cent of infection is low compared to that of kernel smut. Head smut seldom occurs in the eastern half of the state.

Kernel smut is the most destructive disease of sorghum in the United States. It causes a loss of more than $2,000,000 annually in Kansas, and is found wherever susceptible varieties are grown. The per cent of infection always is much greater in the western part of the state than in the eastern half. Thus it seems that conditions most favorable for the growth of sorghums are also most favorable for high smut infection. Fortunately this disease is of such a nature that it can be controlled at a cost not to exceed 1 cent an acre. This includes chemicals, labor, and equipment. Accordingly a loss of $2,000,000 may be prevented at an actual cost of $23,670.

There are two principal methods which may be used for the control of a disease of this nature. These are (1) the production of resistant varieties and strains through selection and hybridization, and (2) seed treatment. There is a great deal to be said in favor of each method, for each has its desirable features. The former is more applicable to a program of crop improvement, which would necessarily consume considerable time, while the latter is a measure of prevention which gives immediate relief, but must be repeated each year. The best balanced program of control is to use both methods simultaneously, relying upon seed treatments to give control until desirable resistant varieties can be secured. Thus it seems that the matter of greatest immediate importance in the control of kernel smut of sorghums is the discovery and application of the most satisfactory methods of seed treatment.

Varieties are known to vary greatly in their susceptibility *(5, 12)* although it has been shown recently *(14)* that milo and dwarf hegari, which have been regarded as highly resistant to the common kernel smut, are sometimes attacked by a different strain of this fungus. It seems, therefore, that seed treatment will continue to be an important method of control. The formaldehyde-soaking method has been the standard treatment for many years, and

although it has given satisfactory results, it has the disadvantage of wetting, swelling, and sometimes injuring the seed *(11, 13)*. For this reason investigations have been conducted to determine whether modifications of this standard method or the use of other chemicals would give satisfactory control without seed injury.

Several things are necessary to bring about the general adoption of any method of seed treatment of grain for smut. (1) The treatment recommended must be effective; (2) it should be easily applied and not cause undue delay in seeding; (3) the cost must, be reasonable; (4) the seed must not be appreciably injured and must be easy to handle after treatment. With these things in mind, various experiments have been conducted.

Much experimental work has been done with seed treatment for other cereals, especially wheat, but little has been done relating to the sorghums. It is not the intention of the authors to review, in this bulletin, the literature on seed treatments or the injury produced by fungicides, as this has been presented adequately in other papers *(1, 3, 6, 7, 8, 9, 10, 15)*.

METHODS AND MATERIALS

The studies herein reported were conducted for the most part at Manhattan, Kan., during the period 1918 to 1925 inclusive.[3] Preliminary studies showed that a number of factors were important in connection with treating sorghum seed. Varieties such as Red Amber and BlackAmber sorgos in which the glumes often adhere to the seed, were found to be injured less by certain seed treatments than varieties in which the seed does not retain the glumes. It was also found more difficult to control smut in varieties in which the seeds retain their glumes, this being especially noticeable in some of the treatments. Hence it was deemed advisable in these experiments to use several varieties, including some the seeds of which retain their glumes. It was also found that well-matured sorghum seed, free from soft, starchy or cracked grains, will withstand very severe chemical treatments without injury, while poor-grade seed is readily injured even if mild fungicides are used. These results are in close agreement with the experiments in the western United States on treatment of seed wheat. It therefore was thought necessary to consider carefully the maturity of the seed in conducting fungicidal treatments.

The sorghum seed used in all experiments was smutted by mix-

3. The authors are indebted to Frank Van Haltern and Ivan White for their assistance in these studies in 1918 and 1919.

ing with viable kernel smut so that each kernel or seed received a heavy, uniform coating of spores. This method covers the seed with much more inoculum than usually occurs under farm conditions, giving the seed mass a dusty brown appearance due to adhering smut spores. The formaldehyde was analyzed before use, and its strength determined. Thirty-seven per cent or higher was considered full strength. In the dry formaldehyde treatments the ordinary tin hand sprayer of one quart capacity was used for applying the solution in 1918 and 1919, but in 1920 to 1925, inclusive, a definite number of cubic centimeters of liquid were measured and applied to a measured quantity of seed. For this purpose an atomizer was attached to a graduated cylinder in such a manner that direct readings of the amount of solution used could be made.

In 1919 and 1920 some experiments were conducted to ascertain the effect of dry heat treatments on the viability of the seed and their value in the control of kernel smut. Several varieties of sorghum were used, and the results are considered representative.

In 1921 to 1925, inclusive, various commercial seed-treating compounds were used. Some were applied as dusts, while others were used in solutions for soaking the seed, according to the directions specified by the companies manufacturing them.

In 1918 and 1919 comparatively large samples of seed were used in the various treatments, *i.* e., from a half peck to a peck, while in the seasons 1920 to 1925, inclusive, samples of half a pint to a pint were used. By careful measurements of definite small quantities of seed and chemicals it was found that accurate results could be obtained.

In the field experiments on smut control an effort was made to examine from 100 to 300 heads from each treated sample. Rows from 75 to 100 feet long usually contained about that number of heads. It has been found that the seed of the most susceptible varieties when thoroughly smutted and planted at Manhattan under environmental conditions most favorable for the development of smut, will average less than 50 per cent of smut infection. The amount of infection and the susceptibility of varieties which were artificially smutted have been studied in detail and the results presented in another paper *(12)*. Sufficient, land for replication of treatments was not available, but check or control rows were grown at frequent intervals in all of the plots for comparison.

During the seasons of 1918 to 1922, inclusive, the total number of plants per row was counted, the plants with smutted heads noted,

and the per cent of smut calculated from these figures. In 1923 to 1925 the total number of heads in each row was counted, the number of smutted heads noted, and the per cent of smut determined on this basis. The latter is perhaps more accurate than the former method, since it provides an accurate means of classifying plants which have several heads, part of which are smutted, while the remainder are smut free. While partially smutted heads sometimes were found, they occurred rarely, and in most cases were merely smutted heads containing a few normal seeds. The proportion of such heads seemed to vary with the variety. Such heads when found in these experiments were classified as smutted.

THE EFFECT OF FORMALDEHYDE ON THE VIABILITY OF KERNEL SMUT SPORES

The first experiments were conducted in 1918. Their object was to determine the effect of different periods of treatment with formaldehyde on the germination of smut spores. They sought both to ascertain whether the time of soaking could be reduced from one hour to only a few minutes, and to determine the effectiveness of the dry formaldehyde treatment.

Seeds of Red Amber and Kansas Orange sorgos and Blackhull kafir were smutted and treated with a 1-240[4] solution of formaldehyde for periods of 5, 10, 15, 20, and 30 minutes, respectively. The treated seed was then washed with sterile water and the wash water from each treatment centrifuged to recover the smut spores. A number of germination tests were then made of these spores. The results indicated only a slight reduction in germinability with a treatment of five minutes, but that each increase in the length of soaking beyond that point caused greater reduction in the number of spores which were able to germinate. Less than 10 per cent of the spores germinated when treated for 20 minutes. Practically the same results were secured from the 30-minute treatment. These results indicated that periods of soaking, shorter than the one-hour treatment which was being recommended, might be expected to give satisfactory control of kernel smut.

The dry formaldehyde treatment also was tried during this season. Seed of Red Amber sorgo was treated in a number of different ways, including full-strength formaldehyde and the half-formaldehyde and half-water solution generally recommended for treating oats. The solutions were applied to a part of the samples at the rate rec-

4. That is 1 part of formaldehyde to 240 parts of water, or 1 pint of formaldehyde to 30 gallons of water.

ommended for oats and to others at three times that rate. Some seed was covered for five hours and other seed covered for eight hours after treatment and the spores were then washed off and examined for germinability as described above. The results obtained were not, entirely conclusive but indicated : (1) Full-strength dry formaldehyde applied at three times the rate used for oats, killed practically all of the smut spores; (2) a solution of half formaldehyde and half water was less effective, regardless of the rate of application or time of covering the seed after treatment; (3) there seemed to be little difference in reduction of spore germination obtained from covering the seed for different lengths of time; (4) the glumes retained by Red Amber sorgo seemed to afford the seed and the smut spores considerable protection from injury.

THE EFFECT OF FORMALDEHYDE TREATMENT ON SEED GERMINATION AND CONTROL OF SORGHUM KERNEL SMUT

Experiments in 1919

Experiments in 1919 were planned to determine the effect of various formaldehyde treatments on the viability of the seed and on smut control in field trials. Blackhull kafir of excellent quality was obtained from the Department of Agronomy and used for this purpose. Both the dry and the standard soaking methods were used.

In the dry treatments a No. 2 shovel, found to hold about two quarts, was used for measuring the seed, an attempt being made to conduct the work as it would be done in farm practice. The solution was applied with a hand sprayer. A stroke of the sprayer piston was the unit employed in measuring the rate of application. A single stroke is referred to hereafter as a single dose, two strokes as a double dose, etc. Three separate sprayers were calibrated, from which it was found that one cubic centimeter of solution was ejected at each stroke of the piston. It is realized that while this is the actual method followed in farm practice, it has its disadvantages from an experimental standpoint. More accurate results might be expected from the use of accurately measured quantities of seed and of solution. Nevertheless the data obtained, as will appear later, clearly demonstrate the limitations of the dry formaldehyde method of treatment for sorghum smut.

After each dry treatment the seed was poured immediately into glass jars provided with tight-fitting covers. The covers were clamped on and the jars shaken to distribute the moisture and gas

throughout the mass of seed. The jars were kept covered for varying periods of time, after which the covers were removed for a few moments while sufficient grain was removed for a germination test and for field plantings. The covers were then replaced and the seed left for longer periods of storage, when additional samples were removed for germination. The seeds treated by the soaking method were dried immediately after treatment and then stored in suitable containers until germination tests could be made. It will be noted in Table I that four separate samples mere used for each experiment. Two germination tests were made of each sample after definite periods. These are designated as first test and second test. All germination tests were made by Mrs. E. P. Harling of the Department of Agronomy, using standard seed-laboratory methods.

The treated seed was planted in rows 75 feet long, each treatment occupying a separate row. After the plants were about six inches tall, they were thinned to about one plant per foot. The smut counts were made as soon as the entire plot was fully headed. The total number of plants and the number of plants bearing smutted heads were counted, and the per cent of smutted plants calculated. Plants with part of the heads smutted and part unsmutted were counted as smutted plants. Table I shows the results obtained from the experiments conducted in 1919.

There is a slight general reduction in the germination of seed stored for 68 days after treatment, but there is no consistent reduction which may be said to be due to differences in length or strength of treatment. The quality of the seed seems to be of more importance in so far as injury is concerned than the treatment itself.

The experiments in 1919 indicate: (1) That the soaking method will give more uniform results than the dry method. (2) That short-time soaking treatments (15 to 30 minutes) will give practically as satisfactory results as the longtime (45 to 60 minute) treatments. (3) That in the dry method, the double dosage will give better control of smut in the field than the single dosage,[5] and the triple dosage will be better than the double. (4) That storage of Blackhull kafir seed up to 68 days after treatment with the dry method will not greatly reduce its vitality even where the triple dosage is used. This result, however, appears to depend greatly upon the condition and the maturity of the seed. It should be mentioned that triple dosage, as herein stated, in practice would amount to an application of about two pints of full-strength form-

5. The single dosage is approximately the standard dry formaldehyde treatment for oat smut.

TABLE I.—The effect of formaldehyde on the control of kernel smut and the viability of Blackhull kafir seed.

(Manhattan, Kan., 1919.)

Sample No.	Treatment.	Length of treatment.	Laboratory germination.					Average per cent smut in field.
			First test.		Second test.		Average per cent for both tests.	
			Days after treatment.	Per cent.	Days after treatment.	Per cent.		
1	Soaking 1-240 (*a*)	15 minutes	1	83.0	22	85.5	88.9	3.3
2	do	15 minutes	3	100.0	63	94.0		
3	do	15 minutes	4	92.0	25	97.0		
4	do	15 minutes	8	93.5	68	82.5		
1	Soaking 1-240 (*a*)	30 minutes	1	88.0	22	83.5	90.0	5.6
2	do	30 minutes	3	100.0	63	95.5		
3	do	30 minutes	4	89.0	25	79.0		
4	do	30 minutes	8	94.5	68	90.5		
1	Soaking 1-240 (*a*)	45 minutes	1	83.0	22	82.0	90.0	3.7
2	do	45 minutes	3	94.0	63	96.5		
3	do	45 minutes	4	93.5	25	89.0		
4	do	45 minutes	8	94.0	68	86.0		
1	Soaking 1-240 (*a*)	60 minutes	1	78.0	22	95.0	84.4	3.2
2	do	60 minutes	3	91.0	63	80.5		
3	do	60 minutes	4	81.0	25	78.5		
4	do	60 minutes	8	92.0	68	81.0		
1	Dry single dosage (*b*)	5 hours	1	89.0	22	93.5	94.9	25.3
2	do	5 hours	3	100.0	63	93.5		
3	do	5 hours	4	96.5	25	93.5		
4	do	5 hours	8	98.0	68	95.5		
1	Double dosage (*c*)	5 hours	1	90.0	22	92.0	94.5	17.4
2	do	5 hours	3	96.5	63	89.5		
3	do	5 hours	4	98.0	25	96.5		
4	do	5 hours	8	96.0	68	97.5		
1	Triple dosage (*d*)	5 hours	1	85.0	22	80.0	87.9	11.5
2	do	5 hours	3	86.0	63	89.0		
3	do	5 hours	4	94.5	25	95.5		
4	do	5 hours	8	92.0	68	81.5		
1	Single dosage	10 hours	1	89.5	22	98.0	95.8	25.0
2	do	10 hours	3	100.0	63	97.5		
3	do	10 hours	4	95.0	25	96.0		
4	do	10 hours	8	96.0	68	95.0		
1	Double dosage	10 hours	1	88.5	22	90.5	94.6	18.7
2	do	10 hours	3	100.0	63	94.0		
3	do	10 hours	4	97.0	25	95.5		
4	do	10 hours	8	95.5	68	96.5		
1	Triple dosage	10 hours	1	83.5	22	96.5	92.4	12.0
2	do	10 hours	3	88.5	63	95.5		
3	do	10 hours	4	93.5	25	98.5		
4	do	10 hours	8	93.5	68	90.0		
1	Single dosage	15 hours	1	82.5	22	97.5	91.5	21.9
2	do	15 hours	3	95.5	63	92.5		
3	do	15 hours	4	97.5	25	98.0		
4	do	15 hours	8	100.0	68	88.5		
1	Double dosage	15 hours	1	75.0	22	88.5	91.7	17.4
2	do	15 hours	3	96.5	63	94.5		
3	do	15 hours	4	96.0	25	98.0		
4	do	15 hours	8	96.5	68	89.0		

TABLE I—*Concluded.*

Sample No.	TREATMENT.	Length of treatment.	Laboratory germination.					Average per cent smut in field.
			First test.		Second test.		Average per cent for both tests.	
			Days after treatment.	Per cent.	Days after treatment.	Per cent.		
1	Triple dosage	15 hours	1	85.5	22	82.5		
2	do	15 hours	3	91.0	63	96.0		
3	do	15 hours	4	95.0	25	98.0	91.9	15.1
4	do	15 hours	8	95.0	68	92.5		
1	Control	Untreated	1	97.0	22	no test		
2	do	Untreated	3	100.0	63	no test		
3	do	Untreated	4	97.5	25	no test	.....	31.2
4	do	Untreated	8	100.0	68	no test		
5	Control	Untreated	1	81.5	22	97.5		
6	do	Untreated	3	88.0	63	97.0		
7	do	Untreated	4	81.5	25	97.5	96.0	41.3
8	do	Untreated	8	88.0	68	97.0		

(*a*) The standard treatment, 1 pint of formaldehyde to 30 gallons of water was used.
(*b*) 1 cc. solution to 2 quarts of seed; approximately the standard treatment for oats.
(*c*) 2 cc. solution to 2 quarts of seed.
(*d*) 3 cc. solution to 2 quarts of seed.

aldehyde to 50 bushels of seed. (5) That the number of hours the treated seed is covered after treatment, ranging from 5 to 15 hours, will not greatly affect the vitality of the seed, nor will there be any appreciable difference in the control of smut.

Experiments in 1920

The experiments conducted in 1919 were continued in 1920 with only slight variations. The seed was dusted with smut spores having a high per cent of viability. Sufficient seed of Blackhull kafir for untreated control rows was saved and the rest divided into samples and treated in different ways. All the seed treatments were made on May 21, 1920, and all seed was planted the following day.

In the dry formaldehyde treatments, a small atomizer was attached to a graduated glass cylinder so that a definite number of cubic centimeters of the solution could be applied to a definite quantity of seed. A pint of seed was used for each treatment. The application of 0.14 cc. of 37 per cent formaldehyde per pint of seed is at the rate of 1 pint to 50 bushels. The seed was treated in pint jars by spraying the solution upon it. The lids were then clamped on. The jars were shaken to mix the gas with the seed and kept covered for varying periods of time, then opened and allowed to air.

The seed treated by the soaking methods was spread on clean newspapers and allowed to dry thoroughly, at the end of the period

of treatment. Each sample was then placed in a new paper bag, taken to the field and planted directly from the bag into the row, the treated seed not being handled in the meantime. This was considered necessary to prevent recontamination of the seed. Favorable conditions for the germination of both the seed and the smut spores followed.

Due to an oversight no germination test was made of the seed from these treatments until 100 days after treating. The seed was placed in paper bags and stored in galvanized iron boxes during this period. While no germination records are available to show the effect of storage after treatment, on the viability of the seed, there seemed to be some evidence to substantiate the conclusion that seed injury results where strong formaldehyde solutions are used. Perhaps the best evidence of such a phenomenon lies in the fact that seed planted immediately after treatment gave excellent field stands with no appreciable differences due to different treatments. On the other hand, the germination tests made 100 days after treatment showed very great reductions in the germination per cents, especially where the strong treatments were used. *These results emphasize the importance* of *planting sorghum seed treated by the formaldehyde method very soon after it is treated so as to avoid injury due to storage.*

The methods of procedure in planting, thinning, and calculating the smut per cents were the same as those used in 1919. The results secured are given in Table II.

These data show very clearly the reductions in germinability of sorghum seed which sometimes result from increasing either the strength or the length of time of treatment. The effect was not so great in the wet as in the dry treatments. Thus soaking the seed in a 1-240 solution of formaldehyde for 15, 30, 45 and 60 minutes reduced the germination 15.5, 9.0, 12.0, and 19.5 per cent, respectively, as compared with the untreated seed, whereas the dry treatments reduced the germination in some cases more than 50 per cent. The period of exposure seemed to be less important in reducing germination than the strength of the solution. In this experiment all soaking treatments gave practically complete smut control.

The dry treatments uniformly reduced germination as the strength of the solution was increased. The time of covering after treatment, up to and including fifteen hours, did not seem to affect the amount of seed injury or the smut control materially. The per cent germination and the amount of smut were practically the same

TABLE II.—Effects of formaldehyde on the vitality of sorghum seed and the control of kernel smut.

(Manhattan, Kan., 1920.)

TREATMENT.	Duration of treatment.	Per cent of germination.	Average.	Per cent smutted.	Average per cent smut.
Wet method, 1 pint formaldehyde to 30 gallons of water (1-240)	15 minutes	74.0	62.0	0.0	0.0
do	15 minutes	50.0		0.0	
do	15 minutes	69.5		0.0	
do	30 minutes	59.5	68.5	0.0	0.0
do	30 minutes	66.5		0.0	
do	30 minutes	79.5		0.0	
do	45 minutes	70.0	65.5	0.0	0.0
do	45 minutes	69.0		0.0	
do	45 minutes	57.5		0.0	
do	60 minutes	58.0	58.0	0.0	0.3
do	60 minutes	58.5		1.0	
do	60 minutes	57.5		0.0	
Dry method, 0.14 cc. formaldehyde per pint of seed	5 hours	65.0	65.0	2.2	2.1
do	5 hours	63.5		4.2	
do	5 hours	66.5		0.0	
Dry method, 0.28 cc. per pint of seed	5 hours	56.5	47.5	0.0	0.0
do	5 hours	51.5		0.0	
do	5 hours	41.5		0.0	
Dry method, 0.42 cc. per pint of seed	5 hours	43.0	28.0	0.0	0.0
do	5 hours	20.5		0.0	
do	5 hours	20.5		0.0	
Dry method, 0.14 cc. per pint of seed	10 hours	67.0	65.0	4.7	3.9
do	10 hours	55.5		5.5	
do	10 hours	73.5		1.4	
Dry method, 0.28 cc. per pint of seed	10 hours	62.5	53.5	1.2	0.8
do	10 hours	48.5		1.3	
do	10 hours	49.5		0.0	
Dry method, 0.42 cc. per pint of seed	10 hours	25.0	24.8	0.0	0.0
do	10 hours	23.0		0.0	
do	10 hours	26.5		0.0	
Dry method, 0.14 cc. per pint of seed	15 hours	68.5	69.5	3.9	2.2
do	15 hours	68.5		0.0	
do	15 hours	71.5		2.7	
Dry method, 0.28 cc. per pint of seed	15 hours	58.0	50.6	0.0	0.0
do	15 hours	40.5		0.0	
do	15 hours	53.5		0.0	
Dry method, 0.42 cc. per pint of seed	15 hours	34.0	30.1	0.0	0.0
do	15 hours	33.5		0.0	
do	15 hours	23.0		0.0	
Control, untreated		76.5	77.5	11.4	16.7
do		77.5		17.5	
do		85.0		14.1	
do		71.0		23.7	

whether the seed was covered fifteen hours or only five hours. Excellent smut control was obtained from the use of each of the two stronger dry treatments, but the seed injury was so severe that their practical value is extremely doubtful.

The efficiency of formaldehyde in the control of kernel smut of sorghum is indicated by the average per cent of smut reported in the last column of Table II. In the untreated control plots 16.7 per cent of the plants were infected with smut, while in eight of the thirteen plots planted with treated seed no smut occurred. The highest per cents in any of the treatments were 3.9 per cent in one of the dry treatments and 0.3 per cent in one of the soaking treatments.

The results from these experiments seem to justify the following conclusions :

1. Both the dry and the wet methods of formaldehyde seed treatment reduce the infection in treated rows.

2. The wet method gives better and more uniform control than do the dry treatments, considering the latter as a whole. This is in agreement with the results of 1919. Only one plant out of 1,270 in the rows planted with seed from the soaking treatments showed any smut.

3. Fifteen minutes is sufficient time for kafir seed to soak in a solution of 1 pint of formaldehyde to 30 gallons of water to insure satisfactory control, providing all of the seed is thoroughly wet. This agrees with the results obtained in 1919. Seed which has the glumes adhering, however, should be soaked for longer periods of time as shown by the experiments in 1918 and 1919.

4. As a rule, it is easier to secure complete control of smut with the wet than with the dry formaldehyde treatment. This perhaps may be partially due to the difficulty of applying uniformly the proper amount of spray over the seed to be treated. As a rule less than 50 bushels of sorghum seed is treated on the average farm at any one time. The average farmer finds it difficult to measure fractions of a pint of formaldehyde. This might easily cause errors in the method of application of the dry formaldehyde treatment.

5. Keeping the seed covered for 10 to 15 hours in the dry formaldehyde treatments gives no better control of smut than keeping it covered only 5 hours. This indicates that the spores are killed by the end of a 5-hour period. The important consideration in the dry treatment seems to be the amount of formaldehyde applied rather than the period of application.

THE EFFECT OF THE STRENGTH OF FORMALDEHYDE SOLUTION AND LENGTH OF TREATMENT ON SORGHUM KERNEL SMUT CONTROL

Some preliminary experiment's relating to the effect of soaking in formaldehyde solutions for various periods of time were conducted by the Agricultural Experiment Station several years ago *(13),* but all treatments ranged from 1 to 12 hours. There were none for less than 1 hour. More extensive experiments were begun in 1921 especially to determine the effect of increasing the strength of the solutions and decreasing the time of treatment. The strength of solution and periods of soaking were as follows:

One pint of formaldehyde to 10 gallons of water (1-80). soaking 15 minutes.
One pint of formaldehyde to 15 gallons of water (1-120), soaking 10 minutes.
One pint of formaldehyde to 30 gallons of water (1-240), soaking 30 minutes.
One pint of formaldehyde to 30 gallons of water (1-240), soaking 60 minutes.

The last mentioned is the standard treatment generally recommended for sorghums. A smutted but untreated control was planted with each lot of treated seed.

The seed was obtained from county agricultural agents and growers in various parts of Kansas and represents the principal varieties of sorghum groan in the state. All seed was heavily smutted before treatment by mixing viable spores of kernel smut with the grain. After treatment small samples were taken for laboratory germination tests. As soon as the seed was dry enough to handle, it was planted in the field, a 75-foot row being planted from each lot. Germination in the field was slow and uneven, due to unfavorable weather conditions, but the final stand notes taken on June 30 showed results fairly comparable to those obtained in the laboratory germination test. The effects of the various treatments are given in Table III and summarized in Table IV.

While all treatments resulted in reduced germination as compared with the controls, this reduction was not enough to prohibit the use of any of them except the one with 1 pint of formaldehyde to 10 gallons of water. In this case a reduction of 16.5 per cent in the laboratory germination and of 16.8 per cent in the field stand, when compared with the untreated controls, indicate severe seed injury.

When the plants reached their full growth there was a noticeable difference in the vigor of those of the same variety from seed which had been treated with varying strengths of formaldehyde. This difference became noticeable in the early part of the season in some rows, but was most clearly evident when the plants had reached their greatest vegetative development. In general the plants from seed

which had been treated with the strongest solution (1 pint of formaldehyde to 10 gallons of water, soaked 15 minutes) showed considerable reduction in vigor. This was manifested by a distinct reduction in height and a higher per cent of weak plants. These differences were more marked in some cases than in others. When this behavior was checked with the physical condition of the seed, it was found that the greater reductions in vigor were almost invariably found to be correlated with poorly matured, badly scarred or cracked seed. While about the same per cent of weak plants appeared in the rows planted from seed treated with a solution of 1 pint of formaldehyde to 30 gallons of water, soaked for half an hour, the general appearance of the rows did not indicate such a marked reduction in vigor. In height these rows averaged about the same as those from seed treated with the same strength of solution for 1 hour. Seed soaked 10 minutes in a solution of 1 pint of formaldehyde to 15 gallons of water produced plants seemingly more vigorous than those in the controls. No explanation is offered as to why this appeared to be the case. In general the results indicate that good smut control and slight seed injury are obtained with a solution of 1 pint of formaldehyde to 15 gallons of water in which the seed is soaked for 10 minutes. They also indicate that where the strength of solution is further increased, and the time is slightly increased, considerable seed injury and reduction of vigor are obtained, especially if the seed is of poor quality.

A solution as strong as 1 pint of formaldehyde to 10 gallons of water in which the seed is soaked for 15 miutes causes too great a reduction in germination and vigor to be of practical value. A repetition of the experiment in 1922 gave similar results. The use of that treatment, therefore, was discontinued after 1922. On the other hand, the results indicated that the other soaking treatments merited further trial. They, therefore, were repeated in the seasons of 1922, 1923, 1924, and 1925.

It did not seem advisable, however, to continue these treatments with as many varieties as were used in 1921. Therefore four varieties, Blackhull kafir, Pink kafir, Kansas Orange sorgo, and Red Amber sorgo were chosen for further experiments. These four varieties are susceptible to kernel smut and are widely grown for grain and forage purposes in various parts of Kansas. The seed was obtained each year through the Department of Agronomy of the Agricultural Experiment Station, and was always of good quality.

The results obtained from the various treatments in the seasons of 1921 to 1925, inclusive, are presented in Table V.

TABLE III.—Effect of the strength of formaldehyde solution and length of soaking on vitality of the seed, vigor of plants, and control of kernel smut.

(Manhattan, Kan., 1921.)

VARIETY, SOURCE AND DESCRIPTION OF SEED.	Strength of solution used.	Duration of treatment.	Laboratory germination.	Stand.	Early vigor.	Smut.
		Minutes	*Per cent.*	*Per cent.*		*Per cent.*
"SOURLESS" SORGO, Cottonwood Falls. Brown, clean, hard, well matured, good luster. *Good quality*	1 pt. to 15 gals	10	85.5	80	Strong	0.0
	1 pt. to 10 gals	15	85.5	85	Strong	0.0
	1 pt. to 30 gals	30	85.5	60	Strong	0.0
	1 pt. to 30 gals	60	88.0	75	Medium	0.0
	Control, not treated	.....	93.0	70	Medium	27.5
BLACKHULL KAFIR, Eureka. White, clean, slightly dull, some immature, somewhat starchy kernels. *Fair quality*	1 pt. to 15 gals	10	90.0	70	Medium	0.0
	1 pt. to 10 gals	15	74.5	50	Medium	0.0
	1 pt. to 30 gals	30	87.0	80	Fair	0.0
	1 pt. to 30 gals	60	90.0	85	Fair	0.0
	Control, not treated	.....	85.5	90	Strong	33.7
DWARF BLACKHULL KAFIR, Dodge City. White, small grains, dirty, chaffy, dull, starchy, immature. *Poor quality*	1 pt. to 15 gals	10	73.0	50	Medium	0.0
	1 pt. to 10 gals	15	49.5	60	Medium	0.0
	1 pt. to 30 gals	30	72.0	50	Fair	0.0
	1 pt. to 30 gals	60	72.0	65	Medium	0.0
	Control, not treated	.....	92.5	70	Medium	33.3
BLACKHULL KAFIR, Hutchinson. White, fairly clean, many immature kernels, poor luster, somewhat starchy. *Fair quality.*	1 pt. to 15 gals	10	73.5	70	Strong	0.0
	1 pt. to 10 gals	15	78.0	70	Strong	0.0
	1 pt. to 30 gals	30	85.0	80	Strong	1.3
	1 pt. to 30 gals	60	81.0	75	Fair	0.0
	Control, not treated	.....	89.0	80	Strong	40.9
BLACKHULL KAFIR, Manhattan. White, clean, hard, fair luster, not many starchy kernels. Mature. *Good quality*	1 pt. to 15 gals	10	74.5	75	Medium	0.0
	1 pt. to 10 gals	15	38.5	40	Weak	0.0
	1 pt. to 30 gals	30	55.5	70	Strong	0.0
	1 pt. to 30 gals	60	64.0	75	Medium	0.0
	Control, not treated	.....	85.0	80	Medium	25.5

TABLE III—*Continued.*

VARIETY, SOURCE AND DESCRIPTION OF SEED.	Strength of solution used.	Duration of treatment.	Laboratory germination.	Stand.	Early vigor.	Smut.
		Minutes.	*Per cent.*	*Per cent.*		*Per cent.*
DAWN KAFIR, Hays. C. I. 1340. White, clean, hard, mature, very few starchy kernels, good luster. *Good quality.*	1 pt. to 15 gals.	10	83.5	90	Strong	0.0
	1 pt. to 10 gals.	15	62.0	65	Strong	0.0
	1 pt. to 30 gals.	30	86.5	80	Medium	0.0
	1 pt. to 30 gals.	60	90.5	90	Medium	0.0
	Control, not treated		97.5	95	Fair	22.9
SUNRISE KAFIR, El Dorado. White, clean, hard, mature, very few starchy kernels, good luster. *Good quality*	1 pt. to 15 gals.	10	60.0	65	Strong	0.0
	1 pt. to 10 gals.	15	82.0	85	Fair	0.0
	1 pt. to 30 gals.	30	84.0	85	Fair to weak	0.0
	1 pt. to 30 gals.	60	83.0	85	Strong	0.0
	Control, not treated		87.5	80	Medium to weak	43.7
RED AMBER SORGO, Hays. Clean, hard, mature, good luster. No starchy kernels. *Good quality*	1 pt. to 15 gals.	10	92.0	90	Strong	0.0
	1 pt. to 10 gals.	15	84.5	60	Strong	0.0
	1 pt. to 30 gals.	30	95.0	80	Strong	0.0
	1 pt. to 30 gals.	60	97.0	80	Strong	0.0
	Control, not treated		82.5	90	Strong	20.6
PINK KAFIR, Hays. C. I. 432. Clean, hard, mature, good luster, no starchy kernels. *Good quality*	1 pt. to 15 gals.	10	98.0	90	Strong	0.0
	1 pt. to 10 gals.	15	96.5	90	Strong	0.0
	1 pt. to 30 gals.	30	98.0	85	Strong	0.0
	1 pt. to 30 gals.	60	96.5	85	Strong	0.0
	Control, not treated		99.0	90	Strong	51.3
KANSAS ORANGE SORGO, Manhattan. Brown, clean, hard, few starchy kernels, fair luster. Few immature kernels. *Fair quality.*	1 pt. to 15 gals.	10	62.5	75	Strong	0.0
	1 pt. to 10 gals.	15	44.0	50	Weak	0.0
	1 pt. to 30 gals.	30	68.5	50	Strong	0.0
	1 pt. to 30 gals.	60	69.5	75	Strong	0.0
	Control, not treated		77.0	70	Medium	19.4

TABLE III—*Concluded.*

VARIETY, SOURCE AND DESCRIPTION OF SEED.	Strength of solution used.	Duration of treatment.	Laboratory germination.	Stand.	Early vigor.	Smut.
		Minutes.	*Per cent.*	*Per cent.*		*Per cent.*
EARLY SUMAC SORGO, Hays.						
Clean, hard, mature no starchy kernels. Good luster. *Good quality*	1 pt. to 15 gals.	10	81.0	85	Strong	0.0
	1 pt. to 10 gals.	15	96.0	60	Weak	0.0
	1 pt. to 30 gals.	30	95.5	80	Strong	0.0
	1 pt. to 30 gals.	60	85.5	70	Medium	0.0
	Control, not treated		84.5	85	Strong	8.9

TABLE IV.—Summary of effect of the strength of solution and length of soaking on vitality of the seed, vigor of the plants, and control of smut.

(Manhattan, Kan., 1921.)

TREATMENTS: 1 pint of formaldehyde to—	Duration of treatment.	Number of varieties treated.	Laboratory germination.		Field germination.		Average vigor of plants.			Average smut.
			Average.	Average reduction due to treatment.	Average.	Average reduction due to treatment.	Strong.	Medium.	Weak.	
	Minutes.		*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
10 gallons of water	15	9	71.9	16.5	65.0	16.8	36.3	36.3	27.4	0.0
15 gallons of water	10	9	79.4	7.0	76.3	5.5	72.7	27.3	0.0	0.0
30 gallons of water	30	9	82.9	6.1	72.7	9.1	45.4	27.2	27.4	0.1
30 gallons of water	60	9	83.3	5.1	78.1	3.7	36.4	63.6	0.0	0.0
Controls, not treated		9	88.4		81.8		54.5	45.5	0.0	29.7

TABLE V.—Summary of results obtained from the use of varying strengths of formaldehyde solutions in treating sorghum seed.
(Manhattan, Kan., 1921 to 1925, inclusive.)

Year	1921 (a).		1922.		1923.		1924.		1925.		1921 to 1925.	
TREATMENT.	Average per cent.											
	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
Formaldehyde, 1 pt. to 10 gals. water (1-80), soaked 15 minutes	71.9	0.0	80.9	0.0	.....	.....	.....	.....	.....	.....	76.4	0.0
Formaldehyde, 1 pt. to 15 gals. water (1-120), soaked 10 minutes	79.4	0.0	87.4	1.3	78.9	0.2	87.1	0.0	75.0	0.0	81.5	0.3
Formaldehyde, 1 pt. to 30 gals. water (1-240), soaked 30 minutes	82.9	0.1	94.9	4.8	80.6	1.1	89.1	0.0	86.0	0.0	86.7	1.2
Formaldehyde, 1 pt. to 30 gals. water (1-240), soaked 60 minutes	83.3	0.0	93.1	2.4	91.6	0.1	88.1	0.0	82.0	0.0	87.6	0.5
Controls, not treated	88.4	29.7	94.6	37.5	89.7	13.2	96.1	12.8	82.0	18.3	90.1	22.3

(a) The figures given for 1921 are averages of nine varieties and those for other years are averages of four varieties.

The results for five years indicate that: (1) increasing the strength of formaldehyde solution and decreasing the time of soaking, results in almost as good smut control as the standard method, but causes somewhat more seed injury. (2) Solutions of 1 to 120 and 1 to 80 injure the seed sufficiently to offset their value in controlling smut, as the physical condition of the seed varies and is not always taken into consideration. (3) Treating with a solution of 1 to 240 for 30 minutes showed a slightly higher per cent of smut in 1922, but, the average results for all seasons indicate that this method may safely be used.

THE EFFECT OF THE DRY FORMALDEHYDE TREATMENT ON VITALITY OF THE SEED AND ON SMUT CONTROL

During the period of 1921 to 1925, inclusive, experiments relating to the effect of dry formaldehyde on the vitality of the seed and on smut control were continued. A single solution only, consisting of equal parts of formaldehyde and water, was used. Both the solution and the seed were carefully measured. In 1921, 3cc.[6] of the solution per quart of grain were applied with an atomizer to two separate samples of each of three varieties of sorghum. One sample was covered for 6 hours and the other for 24 hours. In 1922, 1923, 1924, and 1925, two different applications were made, viz., 3 cc. per quart of seed and 6 cc. per quart of seed, both lots being covered for 5 hours. In these experiments the seed was placed in glass jars and the solution applied with an atomizer. The jars were then closed for definite periods, after which the seed was immediately poured out on clean paper, aired a few hours, and planted. Seed treated with the standard solution of 1 pint of formaldehyde to 30 gallons of water was included in each case for comparison. Smutted but untreated seed was included as a control. The effect on smut control was determined in field plantings. The results obtained in these experiments are given in Table VI.

These results show that (1) the dry formaldehyde method is not so effective in controlling smut as the standard soaking treatment; that (2) it causes more injury when the seed is tightly covered during the treatment; and that (3) the unreliability of the dry formaldehyde treatment from the standpoint of seed injury and smut control makes it impracticable for general use.

6. The strength recommended by War Emergency Board of American Plant Pathologists, 1919.

TABLE VI.—Effect of the dry formaldehyde treatment and of the standard soaking treatment on the viability of sorghum seed and smut control.

(Manhattan, Kan., 1921 to 1925, inclusive.)

YEAR AND VARIETY.	Dry formaldehyde treatment.								Standard soaking treatment.		Controls, smutted, not treated.	
	3 cc. per quart of seed.						6 cc. per quart of seed.		1 pt. formaldehyde to 30 gals. water.			
	24 hours (*a*).		6 hours (*a*).		5 hours (*a*).		5 hours (*a*).		Soaked 1 hour.			
	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
	Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
1921.												
Red kafir	38.0	0.0	54.0	0.0	.....	.....	.....	.....	62.5	0.0	77.0	50.0
Dawn kafir	58.0	0.0	66.5	3.8	.....	.....	.....	.....	84.5	0.0	97.0	30.9
Sumac sorgo	81.5	0.0	72.5	2.5	.....	.....	.....	.....	79.5	0.0	91.0	20.2
1922.												
Blackhull kafir	.....	.....	.....	.....	73.0	0.0	63.0	0.0	89.5	0.0	94.5	51.5
Pink kafir	.....	.....	.....	.....	81.5	0.0	57.5	0.0	95.5	9.6	97.0	33.3
Kansas Orange sorgo	.....	.....	.....	.....	83.0	0.0	63.5	5.8	94.0	0.0	96.0	12.1
Red Amber sorgo	.....	.....	.....	.....	86.0	0.0	69.0	0.0	93.5	0.0	91.0	14.7
1923.												
Blackhull kafir	.....	.....	.....	.....	70.3	0.5	67.2	1.8	85.9	0.0	92.9	3.2
Pink kafir	.....	.....	.....	.....	73.7	2.8	72.8	7.7	76.2	0.0	83.4	24.8
Kansas Orange sorgo	.....	.....	.....	.....	76.6	11.6	74.2	8.6	78.0	1.6	89.6	22.4
Red Amber sorgo	.....	.....	.....	.....	90.6	9.2	74.4	8.8	86.6	0.0	92.9	7.7
1924.												
Blackhull kafir	.....	.....	.....	.....	92.5	0.0	60.0	0.0	92.0	0.0	97.0	2.7
Pink kafir	.....	.....	.....	.....	72.0	0.0	70.5	0.0	89.5	0.0	93.0	27.3
Kansas Orange sorgo	.....	.....	.....	.....	86.0	0.0	78.5	0.0	83.5	0.0	98.5	4.5
Red Amber sorgo	.....	.....	.....	.....	72.5	0.0	70.0	0.0	87.5	0.0	96.0	16.3
1925.												
Blackhull kafir	.....	.....	.....	.....	78.0	0.0	63.5	0.0	80.5	0.0	64.0	11.6
Pink kafir	.....	.....	.....	.....	76.5	0.0	67.0	0.0	76.0	0.0	84.0	28.0
Kansas Orange sorgo	.....	.....	.....	.....	81.0	0.0	71.0	0.0	80.5	0.0	88.0	20.9
Red Amber sorgo	.....	.....	.....	.....	82.0	0.0	72.5	0.0	92.5	0.0	92.0	7.5
Average	59.1	0.0	64.3	2.1	79.7	1.5	68.4	2.1	84.6	0.6	90.2	21.0

THE EFFECT OF DRY HEAT ON THE VITALITY OF SORGHUM SEED AND ON THE CONTROL OF SORGHUM KERNEL SMUT

Experiments in 1919

Experiments were begun in 1919 to determine the effect of treating sorghum seed by dry heat for controlling kernel smut. Samples of Red Amber, Sumac, and Kansas Orange sorgos, White milo, Yellow milo, feterita, Pink kafir, and Blackhull kafir were sent to Madison, Wis.,[7] for treatment. A detailed description of the method and apparatus employed follows: The seed were placed in small wire baskets lined with cheesecloth and heated in a small Freas electirc oven equipped with a fan. For the preliminary tests, only 300 to 400 seeds of each sample were used. For the final tests the remainder of each sample was spread out on cheesecloth on the shelf of the oven. The thickness of the layer of seeds was about equal to the thickness of the seed layer in the small baskets. The seeds were germinated with the results indicated in Table VII. The low per cent of germination, as compared with the controls, indicates that the heat seriously reduced the vitality of some of the seed. Of the eight varieties, Blackhull kafir and Sumac sorgo were most seriously injured, while Red Amber sorgo seems to have been injured but little. The glumes retained by Red Amber probably afforded the grain considerable protection.

Plantings were made in the field at Manhattan on May 23, 1919. A few days later a heavy rain packed the soil and subsequent,drying caused it to bake or crust slightly. Only a few plants in the controls emerged, while practically no plants grew in the treated rows. The stand was so unsatisfactory that smut records were not taken at the end of the season.

Experiments in 1920

In 1920 the dry-heat experiments mere repeated, slight modifications being made, especially with regard to the maximum temperatures which were used. Blackhull kafir and Black Amber sorgo only were included. Some of the samples of each variety were heated only, while others were first soaked in a formaldehyde solution consisting of 1 pint of formaldehyde to 40 gallons of water (1:320), the standard formaldehyde treatment for cereals. Other samples were soaked in water before heating. One untreated sample of each variety was kept as a control. The effect on smut, control was determined by planting the treated seed at Manhattan and determin-

7. The dry heat treatments were conducted in 1919 and 1920 by J. G. Dickson of the Department of Plant Pathology, University of Wisconsin, to whom the writers are indebted for much of the data presented here.

TABLE VII.—Effect of dry heat seed treatments on the vitality of sorghum seed.

(Manhattan, Kan., 1919.)

Temperatures at which treated, degrees C.	Duration of treatment in hours.	Per cent germination.							
		Red Amber sorgo.	Sumac sorgo.	Kansas Orange sorgo.	White milo.	Yellow milo.	Feterita.	Pink kafir.	Blackhull kafir.
83 to 84	3.5	.....	.....	.....	.....	.....	.....	.....	81.0
± 85 (a)	20.5	.....	.....	.....	.....	.....	.....	.....	69.5
	24.0	98.0	5.5	42.0	47.8	.....	.....	68.0	56.0
	24.5	.....	.....	.....	.....	57.3	82.0	.....	.....
± 89	18.0	93.3	5.0	37.8	.....	36.5	32.5	46.7	15.0
	24.0	97.0	6.5	23.5	41.0	16.6	58.5	23.3	46.0
± 100	6.0	.....	.....	.....	.....	.....	.....	.....	11.5
	12.0	.....	.....	.....	.....	.....	.....	.....	14.3
	24.0	.....	.....	.....	.....	.....	.....	.....	0.0
Control	.....	99.0	42.0	89.5	97.0	99.0	99.0	99.0	98.0

(a) The plus or minus sign (±) indicates that the temperature varied and was either a little above or a little below the temperature given. The figure recorded was the nearest average temperature at which the seed was treated.

TABLE VIII.—The effect of dry heat seed treatments on the control of kernel smut.

(Manhattan, Kan., 1920.)

TREATMENT.	Duration of treatment.	Temperature at which treated, degrees C.	Blackhull kafir.			Black Amber sorgo.		
			Number of heads.		Percent smutted.	Number of heads.		Per cent smutted.
			Total.	Smutted.		Total.	Smutted.	
Control	No treatment.	.....	177	36	20.3	567	48	8.4
Dry heat	1 hour	± 85	176	59	33.5	424	39	9.1
Dry heat	3 hours	± 70	147	35	23.8	561	66	11.7
Dry heat	3 hours	± 85	261	54	20.6	879	86	9.7
Formaldehyde 1-320 / Dry heat	15 minutes / 2 hours	± 60	202	0	0.0	413	8	1.9
Formaldehyde 1-320 / Dry heat	30 minutes / 2 hours	± 60	146	0	0.0	359	3	0.8
Water / Dry heat	15 minutes / 2 hours	± 60	241	15	6.2	480	48	10.0
Water / Dry heat	30 minutes / 2 hours	± 60	176	21	11.9	526	36	6.8

ing the number of smutted plants in the field. The various samples and treatment given, as well as the per cent of smut infection obtained in the field, are indicated in Table VIII:

The following conclusions may be drawn from these studies:

1. The dry heat alone, as applied in these experiments, does not control kernel smut. Probably the maintenance of a temperature

sufficiently high for periods of time long enough to kill the smut spores would also kill the sorghum seed as occurred in 1919.

2. In the experiments where dry heat alone was used somewhat higher per cents of smut infection occurred than in the controls.

3. Soaking the seed in water before heating seemed to reduce the per cent of smut to a slight extent, especially in the case of kafir.

4. Soaking the smutted seed in a 1-320 formaldehyde solution before heating gave complete control of smut in kafir and nearly complete control in Black Amber; soaking thirty minutes for Black Amber allowed about half the smut infection obtained in the 15-minute treatment.

5. Undoubtedly, the control mentioned in No. 4 was due to the effect of the formaldehyde rather than to the high temperatures. This is shown by the results obtained with the formaldehyde treatments in 1918 and 1919, and by the lack of smut control where dry heat alone was used.

6. Laboratory germination tests were not made, but satisfactory stands were obtained in the field. Temperatures up to 85° C. did not injure sorghum seed to a very marked degree. The maturity of the seed of a variety and the amount of moisture it contains no doubt are very important factors.

THE EFFECTS OF VARIOUS COMMERCIAL COMPOUNDS ON THE VITALITY OF SORGHUM SEED AND ON THE CONTROL OF SORGHUM KERNEL SMUT

The demonstration of the fungicidal properties of copper carbonate in Australia *(4)* and of the organic mercury compounds in Germany stimulated interest in fungicides other than formaldehyde for the treatment of grains for smut. Copper carbonate was introduced and successfully used for bunt of wheat on the Pacific coast *(6, 10)*. Organic mercury compounds were introduced and used for the same purpose in the eastern United States. A number of seed disinfectants similar to the German preparations have been manufactured in this country in recent years. Some of these patent compounds are applied as a dust, whereas it is recommended that others be applied in solution. Many of them owe their fungicidal properties to copper, organic mercury, phenol, cresol, or to a combination of two or more of these. Some are by-products in the manufacture of other chemicals, while others are manufactured expressly for seed-treating purposes.

Seed-treating compounds have been received from several companies by the Agricultural Experiment Station with the request that

they be tried for their fungicidal properties. As many of these as possible have been used in treating wheat for bunt, oats for smut, barley for covered smut, and sorghum for kernel smut. In every case they have been used in the manner recommended by the companies producing them and have been compared with standard methods of seed treatment. Table IX gives the results secured with a number of these compounds used in solution. The standard formaldehyde and copper sulphate soaking treatments are included in each case for comparison.

It is clearly evident that none of these treatments has given better smut control than the standard formaldehyde solution. A number of them seem promising from the standpoint of smut control and freedom from seed injury, however. The increase in vigor of plants from treated seed, which some companies assert results from the use of their compounds, was not observed. However, none of them caused a reduction of vigor similar to that obtained from the use of strong formaldehyde treatments. A particularly interesting point to be observed is the excellent smut control obtained from the use of the two copper-sulphate treatments. The stronger of these solutions seemed to give somewhat better smut control with very little increase in seed injury. This is a method commonly used in India (2) and other foreign countries. If a soaking treatment is to be used, copper sulphate has advantages in its favor over the formaldehyde treatments and would be cheaper than any of the patented commercial compounds.

In view of the results of these experiments it seems reasonable to state that few if any of the commercial disinfectants which are represented here have any marked advantage over the standard formaldehyde and copper sulphate soaking treatments. There may be some advantage in using some of them when the seed is not fully matured, or when cracked or otherwise injured and injury is likely to result from formaldehyde treatment. The following conclusions seem justified on the basis of the experiment's herein reported: *(1)* Chlorophol, Corona No. 620, Semesan, Pythal, Kalimat, and Uspulun, give nearly as good smut control as the standard formaldehyde treatment; *(2)* seed injury is generally less when these treatments are used than when formaldehyde treatments are employed; and *(3)* soaking matured sorghum seed in a. strong solution of copper sulphate for a short time gives excellent smut control and very little seed injury.

TABLE IX.—Effect of various commercial seed-treating compounds on the viability of seed and control of kernel smut of sorghums as compared with the standard formaldehyde and copper-sulphate treatments.

(Manhattan, Kan., 1922 to 1925, inclusive.)

TREATMENT.	Year	Blackhull kafir.		Pink kafir.		Kansas Orange sorgo.		Red Amber sorgo.		Average, all varieties.	
		Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Formaldehyde, 1 pt. to 30 gals. water, soaked 1 hour	1922	89.5	0.0	95.5	0.0	94.0	0.0	93.5	0.0	93.4	0.0
do	1923	85.9	0.0	76.2	0.0	78.0	0.7	86.6	0.0	81.7	0.2
do	1924	92.0	0.0	89.5	0.0	83.5	0.0	87.5	0.0	88.1	0.0
do	1925	80.0	0.0	76.0	0.0	80.0	0.0	92.0	0.0	82.0	0.0
Chlorophol, 1 gm. to 300 cc. water, soaked 1 hour	1922	94.4	0.0	96.5	0.0	93.3	a17.9	97.0	2.0	95.3	4.9
do	1923	93.0	0.0	88.3	0.5	94.4	1.5	94.3	0.0	93.0	0.5
do	1924	91.1	0.0	84.6	0.0	89.0	0.0	94.0	0.0	89.6	0.0
do	1925	88.0	1.5	96.0	4.2	84.0	3.1	88.0	1.6	89.0	2.6
Seed-O-San, 1 gm. to 400 cc. water, soaked 1 hour	1922	97.0	4.0	95.5	5.1	94.0	0.0	98.0	2.8	96.1	3.0
do	1923	95.4	0.8	79.5	2.4	96.5	1.8	96.3	9.4	91.8	3.6
do	1924	96.7	0.8	88.0	0.0	85.5	0.0	96.5	1.0	91.6	0.7
do	1925	92.0	17.5	88.0	11.3	88.0	6.2	88.0	0.0	89.0	8.7
Corona No. 610, 1 gm. to 500 cc. water, soaked 1 hour	1922	95.5	6.5	95.5	5.7	97.5	2.8	95.2	1.9	95.9	4.2
do	1923	95.2	1.8	89.6	7.7	88.2	8.6	94.7	1.0	91.8	4.8
do	1924	98.5	0.0	89.0	2.2	95.0	1.5	93.5	1.8	94.0	1.4
do	1925	88.0	0.0	80.0	3.7	92.0	8.4	88.0	1.9	87.0	3.5
Corona No. 620, 1 gm. to 500 cc. water, soaked 1 hour	1922	97.0	0.0	95.5	0.0	98.5	5.0	96.5	13.0	96.8	4.5
do	1923	87.7	1.3	76.3	1.0	86.4	3.9	89.9	1.2	85.0	1.9
do	1924	92.0	0.0	86.0	0.0	96.0	1.7	95.5	0.9	92.3	0.7
do	1925	96.0	0.0	92.0	2.8	92.0	6.8	92.0	3.0	93.0	3.1
Copper sulphate, 1 lb. to 4 gals. water, soaked 15 minutes	1922	94.0	0.0	90.5	0.0	89.0	0.0	87.5	0.0	90.2	0.0
do	1923	80.0	0.0	76.5	0.9	79.1	0.0	87.4	0.0	80.7	0.2
do	1924	94.5	0.8	89.0	0.0	95.5	0.0	89.0	0.0	92.0	0.2
do	1925	80.0	0.0	68.0	0.0	68.0	0.0	80.0	0.0	74.0	0.0
Copper sulphate, 1 lb. to 10 gals. water, soaked 3 minutes	1923	88.5	0.9	85.2	0.8	82.8	3.9	93.6	2.9	87.5	2.1
do	1924	88.5	0.0	84.5	0.0	89.0	0.0	81.0	0.4	85.7	0.1
do	1925	92.0	0.0	88.0	2.4	60.0	0.9	80.0	0.0	80.0	0.8

TABLE IX—*Concluded.*

TREATMENT.	Year.	Blackhull kafir.		Pink kafir.		Kansas Orange sorgo.		Red Amber sorgo.		Average, all varieties.	
		Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Semesan, 1 gm. to 400 cc. water, soaked 2 hours	1923	92.1	0.0	91.4	5.6	95.7	7.4	96.5	1.8	93.9	3.7
do	1924	91.0	0.0	89.0	0.0	88.5	0.8	92.0	0.5	90.1	0.3
do	1925	80.0	4.0	80.0	2.9	88.0	2.0	96.0	3.5	81.0	3.1
Pythal, 3 gm. to 400 cc. water, soaked 30 minutes	1923	94.2	0.0	87.0	0.0	93.4	3.6	93.8	0.0	92.1	0.9
do	1924	95.5	0.0	84.5	0.0	93.0	0.0	93.0	0.0	91.5	0.0
do	1925	92.0	1.8	84.0	5.8	84.0	3.3	96.0	0.0	89.0	2.7
Kalimat, 1 cc. to 400 cc. water, soaked 30 minutes	1923	87.2	0.6	83.3	5.0	85.6	20.3	97.2	11.8	88.3	9.4
do	1924	95.0	0.0	87.5	0.0	85.5	0.7	93.5	0.7	90.3	0.3
do	1925	84.0	0.0	96.0	0.0	92.0	7.1	96.0	7.0	92.0	3.5
Corona No. 610, 1 gm. to 1000 cc. water, soaked 1 hour	1922	97.5	8.0	93.0	9.4	95.5	21.6	96.5	7.5	95.6	11.6
Corona No. 620, 1 gm. to 1000 cc. water, soaked 1 hour	1922	94.8	5.1	96.5	0.0	96.5	0.0	98.5	4.0	96.5	2.3
Uspulun, 1 gm. to 400 cc. water, soaked 1 hour	1924	89.5	0.0	85.5	0.0	96.0	0.0	96.0	0.9	91.7	0.2
do	1925	96.0	7.6	80.0	2.0	84.0	2.2	92.0	0.0	88.0	2.9
Furfural, 1 gm. to 200 cc. water, soaked 1 hour	1924	92.6	0.0	80.5	20.1	73.5	4.4	93.5	0.5	85.0	6.2
do	1925	76.0	10.5	80.0	31.6	64.0	24.6	76.0	3.9	74.0	17.6
Tillantin "B," 1 gm. to 500 cc. water, soaked 1 hour	1924	88.1	0.0	86.5	2.5	98.0	0.8	82 5	0.0	88.7	0.8
do	1925	76.0	7.8	76.0	22.2	80.0	7.9	96.0	0.0	82.0	9.5
Germisan, 1 gm. to 400 cc. water, soaked 30 minutes	1925	84.0	0.0	.....	.....	84.0	9.5	.....	.....	84.0	4.7
Bayer Compound, 1 gm. to 400 cc. water, soaked 30 minutes	1925	96.0	4.8	.....	.....	92.0	1.6	.....	.....	94.0	3.2
Superkalimat, 1 cc. to 400 cc. water, soaked 30 minutes	1925	92.0	0.0	.....	.....	92.0	19.6	.....	.....	92 0	9.8
Average of all smutted, untreated controls	1922	94.5	50.8	97.0	40.7	96.0	17.3	91.0	14.1	94.6	30.7
do	1923	92.9	7.9	83.4	19.8	89.6	16.5	92.9	7.7	89.7	13.0
do	1924	97.0	2.7	93.0	27.3	98.5	4.5	96.0	16.3	96.1	12.7
do	1925	64.0	11.6	84.0	28.0	88.0	20.9	92.0	7.5	82.0	17.0

(*a*) Recontamination of seed probably occurred.

DUSTING TREATMENTS FOR THE CONTROL OF KERNEL SMUT OF SORGHUMS

The use of copper-carbonate dust for the control of bunt in wheat has been recommended in Kansas and several other states for the last few years. It was apparent from the knowledge gained in the experiments previously reported in this bulletin that if a dust method could be found that would control sorghum-kernel smut, eliminate seed injury, and not cost any more than the formaldehyde method, it would have many advantages. Very shortly after the use of copper-corbonate dust began to be recommended for the treatment of seed wheat, a number of companies began manufacturing other compounds to be used for this purpose. Some of these are copper compounds in various forms while others have organic mercury as their toxic principle. A number of them have been used at the Kansas Agricultural Experiment Station in seed treatments, including sorghum seed.

In these experiments a measured quantity of seed was placed in a jar, paper sack, or other closed vessel and a weighed amount of the compound added. The seed was then shaken until the grain was thoroughly coated with the dust. At the end of the treatment there was usually a small amount of a mixture of the surplus smut spores and treating compound left in the container. A treatment with the standard formaldehyde solution was included as a control. The results of these experiments are indicated in Table X.

It will be observed that in general these treatments are more promising than those commercial preparations which were applied in solution. They caused no appreciable reduction in vitality of the seed and are much more convenient to apply.

The three years' work with copper carbonate indicate that this compound is perhaps the most promising of the dry dust treatments from a practical standpoint. In the experimental plots at Manhattan and in cooperative and demonstration plantings in various parts of Kansas, it has given good smut control and no seed injury. While it will be noted that the standard formaldehyde treatment resulted in slightly better smut control, it caused more seed injury. Copper carbonate is easily and cheaply applied and the seed may be safely stored after treatment. The Dosch copper-lime dust gave satisfactory smut control, and only slight seed injury. Dehydrated copper-sulphate dust gave good smut control, but caused more seed injury than copper carbonate.

"Coppercarb," a form of copper carbonate carrying a low per

TABLE X.—Effect of dust treatments on the viability of seed and the control of kernel smut of sorghums.

(Manhattan, Kan., 1922 to 1925, inclusive.)

TREATMENT.	Year.	Blackhull kafir.		Pink kafir.		Kansas Orange sorgo.		Red Amber sorgo.		Average, all varieties.	
		Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Standard formaldehyde, 1 pt. to 30 gals. water, soaked 1 hour	1922	89.5	0.0	95.5	0.0	94.0	0.0	93.5	0.0	93.4	0.0
do	1923	85.9	0.0	76.2	0.0	78.0	0.7	86.6	0.0	81.7	0.2
do	1924	92.0	0.0	89.5	0.0	83.5	0.0	87.5	0.0	88.1	0.0
do	1925	80.0	0.0	76.0	0.0	80.0	0.0	92.0	0.0	82.0	0.0
Seed-O-San, dust 2 ozs. per bu. seed	1922	99.0	3.3	96.5	9.5	98.0	0.0	95.5	0.0	97.2	3.2
do	1923	83.1	12.8	91.2	8.6	94.4	3.6	90.1	2.7	89.7	6.9
do	1924	90.5	2.1	87.0	16.3	96.5	0.0	93.5	1.2	91.8	4.9
do	1925	84.0	1.9	92.0	23.7	92.0	9.4	96.0	12.1	91.0	11.7
Corona 40S, dust 2 ozs. per bu. seed	1922	98.5	0.0	(*a*)	0.0	97.0	0.0	(*a*)	0.0	97.7	0.0
do	1923	93.7	0.0	87.8	0.0	93.9	1.2	92.4	0.9	91.9	0.5
do	1924	95.1	0.0	86.5	3.4	96.0	0.0	92.0	6.5	92.4	2.5
do	1925	88.0	0.0	96.0	2.8	88.0	3.7	96.0	1.0	92.0	1.9
Copper-carbonate dust (*b*), 2 ozs. per bu. seed	1923	94.2	1.1	91.3	0.0	78.0	0.0	95.2	0.0	89.6	0.3
do	1924	95.5	0.0	87.5	0.0	96.0	0.0	92.0	0.0	92.7	0.0
do	1925	80.0	0.0	96.0	1.8	80.0	0.0	92.0	1.4	87.0	0.8
Dehydrated copper-sulphate dust, 2 ozs. per bu. seed	1923	91.9	0.4	84.4	0.0	87.1	0.0	79.4	0.0	85.7	0.1
do	1924	94.2	0.0	87.5	0.6	93.5	0.0	91.0	0.0	91.5	0.1
Dosch copper-lime dust, 2 ozs. per bu. seed	1923	94.1	0.3	89.6	0.0	83.7	0.3	95.8	0.0	90.8	0.1
do	1924	96.0	0.0	88.5	0.0	88.5	0.0	91.0	0.0	91.0	0.0
do	1925	80.0	0.0	88.0	5.0	76.0	2.8	96.0	0.0	85.0	1.9
Flowers of sulphur dust, 2 ozs. per bu. seed	1923	98.4	1.0	90.1	1.1	89.4	0.4	97.1	0.0	93.7	0.6
do	1924	96.5	0.0	92.5	0.0	98.0	0.0	94.0	0.0	95.2	0.0
do	1925	92.0	1.3	84.0	6.2	80.0	0.0	92.0	0.0	87.0	1.9
"Coppercarb" dust, 2 ozs. per bu. seed	1924	94.8	0.0	89.5	0.0	93.5	0.0	94.5	0.0	93.0	0.0
do	1925	84.0	1.7	84.0	2.9	96.0	1.7	92.0	0.0	89.0	1.6
Corona No. 640 dust, 2 ozs. per bu. seed	1924	95.8	0.0	86.5	0.9	96.5	0.8	94.5	0.0	93.3	0.4
do	1925	84.0	0.0	88.0	3.9	100.0	5.1	84.0	1.3	86.0	2.6

TABLE X.—*Concluded.*

TREATMENT.	Year.	Blackhull kafir.		Pink kafir.		Kansas Orange sorgo.		Red Amber sorgo.		Average, all varieties.	
		Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.	Germination.	Smut.
		Per cent.	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*	*Per cent.*
Corona No. 640S. dust, 2 oz. per bu. seed	1924	95.0	0.0	87.0	5.5	96.5	2.9	91.0	8.8	92.3	4.3
do	1925	88.0	1.1	88.0	13.6	96.0	7.8	88.0	3.7	90.0	6.5
Copper Stearate dust, 2 ozs. per bu	1925	92.0	13.1	84.0	11.8	88.0	7.7	92.0	9.9	89.0	10.6
Niagara Sulfodust, 2 ozs. per bu	1925	80.0	0.0	84.0	3.0	80.0	0.0	84.0	3.5	82.0	1.6
Niagara dusting sulphur, 2 ozs. per bu	1925	80.0	0.0	84.0	0.6	96.0	0.0	92.0	0.0	88.0	0.1
Superfine commercial flour sulphur, 2 ozs. per bu	1925	68.0	0.0	.....	.....	88.0	0.0	.....	.....	78.0	0.0
Colloidal copper, 2 oz. per bu	1925	84.0	15.1	.....	.....	92.0	6.7	.....	.....	88.0	10.9
Mercury compound "B," Roessler & Hasslacher, 2 ozs. per bu	1925	88.0	1.8	.....	.....	96.0	3.1	.....	.....	92.0	2.4
Abavit (German), 2 ozs. per bu	1925	88.0	1.8	.....	.....	76.0	0.0	.....	.....	82.0	0.9
Bayer dust, 2 ozs. per bu	1925	100.0	2.2	.....	.....	96.0	1.2	.....	.....	98.0	1.7
Trockenbeize No. 225V (German), 2 ozs. per bu	1925	96.0	0.0	.....	.....	92.0	4.3	.....	.....	94.0	2.1
Trockenbeize AZIII (German), 2 ozs. per bu	1925	84.0	5.9	.....	.....	88.0	2.9	.....	.....	86.0	4.4
Control, seed smutted not treated	1922	94.5	50.8	97.0	40.7	96.0	17.3	91.0	14.1	94.6	30.7
do	1923	92.9	7.9	83.4	19.8	89.6	16.5	92.9	7.7	89.7	13.0
do	1924	97.0	2.7	93.0	27.3	98.5	4.5	96.0	16.3	96.1	12.7
do	1925	64.0	11.6	84.0	28.0	88.0	20.9	92.0	7.5	82.0	17.0

(*a*) No data available.
(*b*) Analyzing between 50 to 55 per cent copper.

cent of metallic copper (18 to 20 per cent), was used for the first time in 1924 and gave very good smut control with very little seed injury. The results indicate that it can be used safely if a slightly larger amount per bushel is used. Three to four ounces per bushel of seed probably is more desirable than two ounces, as it will then afford protection no matter how badly smutted the seed may be. At present the principal requirements for success in using the copper-carbonate dust treatment seem to be to procure a compound which carries at least 18 per cent metallic copper and which is finely enough divided to insure good covering and sticking qualities.

No extensive experiments have been conducted in which copper carbonate has been used at a rate greater than 2 ounces per bushel. For compounds with a copper content greater than 20 per cent, 2 ounces per bushel seem to be sufficient. If the copper content drops below 20 per cent, there should be a proportionate increase in the dosage.

Much of the sorghum seed on the farm has lumps or broken pieces of the "smut balls" or false kernels scattered throughout the seed. These masses contain thousands of smut spores. It is highly desirable that such seed is cleaned before treatment, especially where the dust treatments are used. Not only will a better grade of seed be obtained, but the possibilities for complete control of smut are much better.

In these experiments copper carbonate was as easily applied to sorghum seed as to wheat and gave about the same degree of smut control in one crop as in the other. In all of these experiments it must be kept in mind that the seed was very much more heavily smutted than grain which is used for seed by farmers. It is doubtful whether a farmer would ever use seed as smutty as that used in these experiments, and it certainly would not be advisable to do so if other seed could be procured. It was necessary to subject the grain to the heaviest possible smutting under experimental conditions, however, in order to ascertain the efficiency of the various treatments under the most severe conditions which would be likely to be encountered under practical farm usage.

One of the most promising treatments seems to be some form of sulphur dust. Flowers of sulphur has been used for three years with very satisfactory results, the control of smut being nearly equal to that obtained with copper carbonate. Three brands of superfine sulphur were used in 1925 with excellent results. The only objection to flowers of sulphur seems to be its inferior sticking qualities. The

superfine forms stick much better than flowers. The cost of sulphur dust is very much less than the cheapest copper carbonate. Further study is being conducted with various grades of sulphur.

The results as a whole may be taken to indicate that (1) copper carbonate, dehydrated copper sulphate, Dosch copper-lime, flowers of sulphur and the finer makes of sulphur dusts, Corona 40S, Corona 640, and Coppercarb, give almost as good smut control as the standard formaldehyde treatment; (2) the dust treatments all produce less seed injury than formaldehyde treatments; and (3) copper carbonate and forms of sulphur dusts seem to be the most promising of all seed treatments from the standpoint of ease and rapidity of application, cheapness, smut control, and freedom from seed injury.

SORGHUM SEED TREATMENTS IN DEMONSTRATION FIELDS IN KANSAS, 1924 AND 1925

The results obtained in 1923 indicated that copper-carbonate dust might be successfully used under farm conditions. Before it could be recommended to farmers, however, it was necessary to give it a thorough trial under farm conditions. Arrangements were made with Mr. E. A. Stokdyk, extension plant pathologist, to conduct a number of demonstrations on farmers' fields in various sections of the state. Several counties in western Kansas experienced large losses from kernel smut of sorghum in 1923, and a number of farmers in those counties asked for demonstration tests to be placed on their farms. Seven tests were made in Hodgeman county, four in Ness county, and two in Rush county. In each case an untreated control plot and a plot planted to seed treated with the standard formaldehyde solution were included. Blackhull kafir, Pink kafir, Red kafir, Sumac sorgo, Orange sorgo, and "African millet" comprised the varieties treated. The plots varied in size from half an acre to four acres. All treatments were made by Mr. Stokdyk in demonstration meetings at the farms where the seed was planted.

Excellent smut control was secured in these plantings. In every case the copper-carbonate dust treatment gave as good or better smut control than the formaldehyde treatment. In only one case was there more than a trace of smut in the copper-carbonate plots, while the control plots had from 3 to 30 per cent of smut. It was found, also, that fanning the seed was not absolutely essential for smut control. Many of the lots of seed treated with copper carbonate had a large per cent of whole or broken smut balls. These smut balls were not removed, the seed being treated just as it came

from the bin. The most striking point about the copper-carbonate treatments was the greatly increased stand in those plots compared with that in the control plots. In some cases the stands were 20 to 50 per cent better in the copper-carbonate plots than in the control plots.

This work was repeated in 1925 by Mr. D. R. Porter, extension plant pathologist during that year. Plots were planted on the fields of thirty-five farmers in five counties. Kafirs and sorgos were included. Counts were made to ascertain the per cent of smut balls in the seed before treatment. Wherever possible a treated and an untreated plot were planted from the same lot of seed. It was found that where the seed contained a small per cent of smut balls the copper-carbonate treatment gave perfect control, while the untreated control plots were badly smutted. Where the seed contained more than 20 per cent of smut balls, the treatment did not always give perfect, control, but the amount of smut was reduced to 4 or 5 per cent.

The results were so outstanding that seed treatment by this method is becoming very popular among growers. This in itself constitutes the best sort of indorsement for this method of treatment. The results of these demonstrations, together with the results obtained in experimental plantings at Manhattan clearly demonstrate that the copper-carbonate dust treatment gives excellent control of kernel smut of sorghums and can be safely recommended for general farm use.

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12-2199