THE EFFECT OF FUNGICIDAL SEED TREATMENT ON WHEAT PLANT EMERGENCE AND BUNT CONTROL

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1932

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Botany and Plant Pathology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

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INTRODUCTION

The purposes of this investigation were to determine the effect of several seed treatment fungicides on the amount of wheat seedling emergence, if increased emergence would be sufficient to justify treating the wheat seed independent of bunt control, and how effective the various fungicides would be in controlling bunt.

The treatment of wheat seed with a fungicide to control bunt and to give more uniform stands, was a practice generally recommended throughout the United States by the state experiment stations, the United States Department of Agriculture, and the manufacturers of fungicides. Since many new fungicides were made available and recommended for seed treatment by chemical companies, information as to the value of these products was needed. One or more of them could have been more practical for use than New Improved Ceresan which was generally used.

Over thirteen million acres of wheat are seeded in Kansas each year. Of this acreage approximately five million acres are planted with seed treated with a fungicide according to King (4). Comanche and Pawnee varieties of wheat which were released by the Kansas Agricultural Experiment Station have resistance to bunt. At the present time they occupy over half of the Kansas wheat acreage. It was not known whether it was necessary to treat seed of these varieties to prevent bunt from developing under farm conditions. Therefore, it was hoped that from this work it could be learned whether or not it pays to treat wheat seed in Kansas with a fungicide from the standpoint of the effect on emergence and the effect on yield when bunt is not a factor. If it does pay from the standpoint of saving seed or increasing yields, then all wheat seed planted in Kansas should be treated, including the bunt resistant varieties.

The average cost of the fungicide for treating enough wheat seed to plant an acre in Kansas with Ceresan was approximately four cents. If such treatment would increase the stand five percent, and if one bushel of seed were planted to the acre, the saving of seed would be equal to three pounds which would be worth twelve cents. This could mean a saving of an estimated 500,000 bushels of wheat seed in Kansas each year, or an annual net saving of approximately $900,000 to Kansas wheat growers at 1953 prices of Ceresan and wheat seed. This large figure would be the value of seed saved from a five percent increase in stand due to treating the seed and would not include the value of any increase in yield nor the value of bunt prevention.

If there was not a fungicide available for the control of bunt, in a matter of perhaps 10 or 15 years the annual loss due to bunt would probably amount to 5 to 15 percent of the Kansas wheat crop. A loss of ten percent would be a loss of $35,000,000 annually to Kansas wheat growers at present prices. Therefore, it is very important that the seed treatment materials used be effective in controlling bunt.

MATERIAL AND METHODS

Emergence Tests

Seed. Two lots of seed were secured each year for conducting the major part of the experiments. The tests were conducted in the years 1947, 1948, 1949, 1950, and 1951. One lot of plump, bright, high germination certified seed of Pawnee variety and one lot of somewhat inferior Pawnee seed was secured each fall. The somewhat inferior seed in 1948 was grain which had sprouted 44 percent in the head before harvest but germinated 94 percent in the seed germinator. That used in 1949 was medium shriveled and had a germination test of 94 percent. In 1950 the inferior seed used was bright, plump, one-year-old grain. In addition, during 1948, 1949, and 1950 samples of uncertified seed which was to be used by farmers for planting were secured to compare with the certified and inferior seed tested more extensively. The farmers' seed planted in November of 1950 did not emerge very well due to dry weather and blew out so that no satisfactory counts could be made.

Hot Water Treatment. Part of the good certified Pawnee seed was treated with hot water in the fall of 1947 and this lot of seed was used instead of naturally inferior seed. It was desired to learn what effect some of the various seed treatment fungicides would have on hot water treated seed. The seed was treated with hot water according to the customary method for control of loose smut. This included soaking the seed for 10 minutes at 129 degrees Fahrenheit. The seed was then placed in a thin layer on newspaper covered tables in the laboratory to dry. The fungicides were applied after the seed was dry.

Fungicides. The fungicides were applied to one liter seed samples approximately three days before the first date of planting each fall. Approximately one-third of a sample was put into a shaker, which was a two-pound coffee can, one-half of the amount to be used of a dust fungicide was put in, another one-third of the seed was added, the other one-half of the fungicide put in, and then the balance of the seed was added. The lid was put on and the can was shaken until the fungicide was thoroughly distributed over the surface of the kernels. One-tenth of an ounce of fungicide was applied above the regular rate per bushel of seed to make up for that lost between treating and planting. Panogen, which is a liquid product, was applied in 1949 by pouring it onto the seed exactly like the dusts were applied. In 1950 it was poured onto the inside wall of the can before the seed was put in. Each sample of seed was poured into a paper bag after shaking. These were allowed to remain open on a shelf in the laboratory until time for counting the seed for the first date of planting. The volatile mercury samples were kept a few feet away from the other samples. The shaker was washed out with detergent in water and dried out between each treatment.

Table 1. Application rates of the fungicides per bushel of seed and the name of the manufacturer of each product.

Product	Rate per bu.	Manufacturer
New Improved Ceresan (5% ethyl mercury phosphate (3.8% Hg)	1/2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
Ceresan M (7.7% ethyl mercury p-toluene sulfonanilide (3.2% Hg)	1/2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
Copper carbonate (50% metallic copper)	2 oz.	Pittsburg Plate Glass Co., Milwaukee, Wis.
Arasan (50% thiram (tetramethylthiuram disulfide))	2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
Spergon (96% chloranil (tetrachloro-para-benzoquinone))	2 oz.	U. S. Rubber Co., Naugatuck, Conn.
Panogen (2.1% methyl mercury dicyan diamide (1.4% Hg))	3/4 fl. oz.	Panogen Inc., New York, N. Y.

Planting. The experiments were conducted in the field so that conditions would be the same as those which confront the farmer. In 1947 and 1950, 200 seeds were planted per 10-foot row. In 1948 and 1949, 150 seeds were planted in each 8-foot row. Treatments were randomized in each of the 5 replications. The seeds were counted by mixing well and lifting a handful out onto a clean sheet of typing paper. They were then counted out in units of five with a knife blade so that a minimum of the fungicide was removed from the seed. A different sheet of paper was used for each fungicide so there would be no possibility of getting a mixture of fungicides on the seed. The seeds were put into small paper packets after counting. Furrows in the soil were made with a hoe and the seed was planted by hand. The hands were wiped off on cloth between each fungicide, even if no fungicide could be seen on the hands after planting a row. The rows were filled back with dirt with the hoe and the soil firmed with the feet. The depth of planting was as near that of recommended drill planting as possible.

Counting. Emergence counts were made when the wheat seedlings were approximately 2 inches tall. This made it necessary to count late plantings the following spring to allow for completion of emergence.

Bunt Control Tests

Seed. Good seed of Red Chief wheat was secured each fall of the years from 1947 to 1950. This variety was secured because of its high susceptibility to stinking smut (bunt). Such a variety is necessary in order to get a good test of the value of a fungicide in controlling bunt. Bunt inoculum from the previous crop was secured from Dr. Earl D. Hansing, Kansas State College Plant Pathologist. The smut balls had been crushed and consequently the bunt was powdered. This bunt was mixed with the seed by shaking together in a can so that each kernel was completely covered with bunt.

Treating. The above bunted seed was measured out in one liter lots and each lot treated with a fungicide except for the control or check lots. The treatment process was the same as that used for treating seed for the emergence plots discussed earlier under Material and Methods. Each fungicide was on the seed at least three days before the first date of planting.

Table 2. Names, rates, and manufacturers of fungicides used during the years 1947 to 1950.

Product	Rate per bu.	Manufacturer
1. Ceresan M	1/2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
2. Ceresan M	1 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
3. New Improved Ceresan	1/2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
4. New Improved Ceresan	1 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
5. Arasan	2 oz.	E. I. du Pont de Nemours & Co., Wilmington, Del.
6. Copper carbonate	2 oz.	Pittsburg Plate Glass Co., Milwaukee, Wis.
7. Chlorinated Hydro-carbon No. 4	2 oz.	Penn Salt Mfg. Co., Philadelphia, Pa.
8. Spergon	2 oz.	U. S. Rubber Co., Naugatuck, Conn.
9. MTH Control N-3358	2 oz.	U. S. Rubber Co., Naugatuck, Conn.
10. N-Nitroso-Phthalimidine	2 oz.	U. S. Rubber Co., Naugatuck, Conn.
11. Phygon-XL	2 oz.	U. S. Rubber Co., Naugatuck, Conn.
12. KF Deleware	1/2 oz.	Unknown
13. Panogen	3/4 fl. oz.	Panogen, Inc., New York, N. Y.
14. Panogen	1.5 fl. oz.	Panogen, Inc., New York, N. Y.

Table 2. (concl.)

Product	Rate per bu.	Manufacturer
15. F. W.	2.4 oz.	Plant Products Corp., Blue Point, Long Island, N. Y.
16. Mercan A	1 oz.	John Powell & Co., Inc. New York, N. Y.
17. Mercan B.	1 oz.	John Powell & Co., Inc. New York, N. Y.
18. Aldrin (emul. conc. 25%)	1.5 fl. oz.	Julius Hyman & Co., Denver, Colo.
19. Aldrin (wet. powder 25%)	3 oz.	Julius Hyman & Co. Denver, Colo.
20. Dieldrin (emul. conc. 25%)	1.5 fl. oz.	Julius Hyman & Co. Denver, Colo.
21. Dieldrin (wet. powder 25%)	3 oz.	Julius Hyman & Co., Denver, Colo.
22. Lindane (wet. powder 25%)	3 oz.	Commercial Solvents Corp., New York, N. Y.

Planting. The treated seed was measured out so that there were approximately 200 seeds per packet. The seed was planted in 10-foot rows, the same as that for the emergence plots except that four replications were used instead of five.

Counting. Results were obtained by counting the heads and determining the percentage of bunted heads.

REVIEW OF LITERATURE

Emergence

Better stands of wheat are often obtained from treating the seed with a proper fungicide. The chemical kills the bacteria and fungi on the seed and also prevents organisms in the soil from attacking until a sprout is produced. If the organisms are allowed to attack, they sometimes use the food stored in the seed that the sprout needs to produce roots and leaves to get the young plant established. Wallin (9) made a study of the progress of a bacterium in attacking the seed and seedling. A few diseased seedlings developed from nonwounded infested wheat seeds. The bacteria were found to penetrate through wounds in the pericarp covering the embryo; infection of the plumule occurred through wounds or stomata on the coleoptile. The bacteria spread rapidly through these tissues and into the enclosed foliage leaves. Since the first foliage leaf is adjacent to the coleoptile, it became infected before emerging from the coleoptile. The infected leaf, by elongation, carried the bacteria into the aerial parts of the seedling.

A survey by Bamberg (1) in Minnesota in 1936 revealed that several counties had from 5 to 40 percent seedling infection from untreated seed. About half of the fields examined were infected. Grain from treated seed was relatively free from seedling blight.

Tervet (8) made a survey of the microflora of wheat seed from Minnesota, North Dakota, and South Dakota in 1943 and 1944. Helminthosporium spp. were the most common pathogenic fungi on the wheat seed. The highest average infection from a locality was St. Paul, Minnesota, with 52.6 percent and the lowest was 8.2 percent from Brookings, South Dakota. The highest infection of Fusarium spp. principally Gibberella saubinetti (G. zeae) in southern Minnesota and South Dakota occurred on samples from Brookings, South Dakota, where 58.3 percent of the seeds were infected.

In general, seeds tended to carry more Helminthosporium than Gibberella except in eastern South Dakota where Gibberella appeared to be especially severe.

Brentzel (2) studied the cause of black point discoloration at the germ end of durum and hard wheat seed. Damage was found to result from infection by Alternaria and Helminthosporium, a little Gibberella scab, some bacterial infection, and a number of weakly parasitic and nonparasitic molds. Seed germination and seedling vigor in most samples were improved by Ceresan treatment, according to Brentzel.

Leukel (5) conducted some experiments in 1951 with treated seed of bunted Ulka wheat. He concluded that none of the treatments had any appreciable effect upon germination in steamed soil two months and six months after treating (Table 3).

Bunt Control

Melchers (7) stated that before the year 1900, Kellerman and other investigators of the Kansas Agricultural Experiment Station tested 51 different chemicals and other treatments over a period of years in an effort to find a good practical control for bunt. Kellerman concluded from the tests that of these, three treatments, viz., a 5 percent copper sulfate solution soak for 24 hours, Bordeaux mixture 36 hours, and potassium bichromate 5 percent solution for 20 hours, gave the best results on bunt control.

In the year 1901, according to Melchers (7), Kellerman reported that bunt was effectively prevented by treating the seed with hot water at a temperature of 131 degrees Fahrenheit for 15 minutes. Kellerman stated that, "for cheapness, as well as for greater efficiency (without injury to seed) this is recommended over all other fungicides". However, after several years of additional experimental work on bunt control in Kansas and elsewhere, the conclusion was reached that the copper sulphate (bluestone) and formaldehyde methods were the most practical and effective treatments. These were still used for bunt control in Kansas in 1914. However, because of the large amount of labor required by these methods they were not generally used by wheat growers.

Table 3. Percent emergence from treated seed of smutty Ulka wheat after storage for 2 months and for 6 months at room temperature and then planted in steamed soil held at 15° C. for 4 days and then at 25° C. until emergence; and, percent of smutted heads grown from this seed in field plots at seven stations, 1951.*

Seed treatment[a]			Percent emergence after		Percent infection in plots planted at							
Name of Material	Rate bu.	per 500 cc.	2 mos.	6 mos.	Urbana Ill.	Madison Wis.	Bozeman Mont.	Aberdeen Idaho	Pullman Wash.	Fargo N. Dak.	Beltsville Md.	Average
Check			86	93	22.2	7.5	81.0	92.0	97	28.8	89.0	59.6
Ceresan M	1/2 oz.	0.2 g.	88	93	0.2	0.1	5.5	5.8	6	t	0.6	2.6
Aagrano	1/2 oz.	0.2 g.	93	93	3.0	0.1	7.3	6.1	16	0.5	8.5	5.9
Agrox	1/2 oz.	0.2 g.	87	88	11.0	0.4	16.8	21.8	54	1.5	0.8	15.2
L-224	1/2 oz.	0.2 g.	90	93	9.0	0.6	31.1	31.7	73	2.0	8.9	23.3
Dynacide	1/2 oz.	0.2 g.	89	93	9.0	0.4	21.3	33.1	62	5.4	1.7	19.0
Leytosan	1/2 oz.	0.2 g.	92	91	8.0	0.7	15.6	24.0	55	2.1	1.3	15.2
K.F. 467	1/2 oz.	0.2 g.	91	91	.5	0	1.9	2.6	2	t	0	1.0
Mercuran A. S.	1/2 oz.	0.2 g.	94	92	8.0	0.4	16.2	9.7	31	4.6	3.1	10.4
Ceresan M slurry	1/2 oz.	3.0 cc.	93	91	.2	0	1.5	0	t	0	0.1	0.3
Aagrano slurry	1/2 oz.	3.0 cc.	90	85	0	0	.4	0	0	0	0	t
Panogen (conc.)	3/4 oz.	0.3 cc.	94	94	0.6	0	2.2	0.5	4	0	0	1.0
Check			88	91	22.0	12.4	85.0	95.0	97	36.8	91.0	62.7
Panogen (dilute)	3/4 oz.	3.0 cc.	94	93	0	0	1.0	0	0	0	0	t
Mercuran A. L.	1/2 oz.	3.0 cc.	92	95	0.3	0	.9	0.7	t	0	0	0.3
Vancide 51	3 oz.	4.0 cc.	95	93	2.0	0.1	11.2	11.9	28	0.4	5.1	8.4
Arasan	1 oz.	0.4 g.	92	93	2.0	0	20.4	16.8	36	4.3	3.0	11.8
Copper carbonate	2 oz.	0.8 g.	89	89	1.0	0	7.0	—	10	0.6	0.6	2.7
Phygon	1 oz.	0.4 g.	90	87	1.0	0.1	2.0	12.1	12	0.8	0.1	4.0
Spergon	1 oz.	0.4 g.	92	89	.7	0	4.2	8.7	7	0.3	0.3	3.0
C & C 640	1 oz.	0.4 g.	90	90	.3	0	4.3	25.6	4	0.3	0.3	5.0
C & C 5400	1 oz.	0.4 g.	89	88	1.0	0.2	9.9	22.5	26	0.6	2.4	9.0
Parson's S.S. Dust	1/2 oz.	0.2 g.	87	89	18.0	4.6	58.8	84.5	97	16.8	91.0	53.0
Anticarie	1/2 oz.	0.2 g.	88	92	5.0	0.1	9.0	2.4	11	7.0	1.6	3.7

[a]Treatments 10 and 11 were applied as slurries; 12 was applied as a concentrated "quick-wet" treatment; and 14 and 15 were applied like slurries except that the active ingredients were in solution instead of being in suspension. The remaining materials were applied as dusts.

*This table copied from the reference Leukel (5).

Copper carbonate was tried in California in 1920 for bunt control according to Melchers (7). It was immediately tried by other stations including Kansas. The copper carbonate dust was applied to the seed simply by mixing the seed and the dust together in a rotary barrel or other suitable mixer. This made it practical for growers to treat several hundred bushels for seeding large acreages.

In the early 1930's New Improved Ceresan was recommended by the manufacturer as a seed treatment material to control bunt. It was tried by experiment stations and found to be satisfactory. The advantages it had over copper carbonate were that it made the cost less per bushel of seed treated and it did not bind the seed in the drill box. However, copper carbonate was not so irritating to work with and the seed could be planted as soon as treated. New Improved Ceresan had to be on the seed at least 24 hours before planting. Both products were used for some time, but as time went on more Ceresan was used to the exclusion of copper carbonate. In the 1940's nearly all seed treating was done with Ceresan.

Steps were taken by the manufacturer of Ceresan and others to produce a product which was less irritating to workers. The flying dust during seed treatment caused some workers to become sick and it irritated others. E. I. duPont de Nemours and Company, Incorporated, Wilmington, Delaware, released Ceresan M in the late 1940's after it had been tried by the United States Department of Agriculture and state experiment stations. It had practically the same characteristics as New Improved Ceresan but was somewhat less irritating to use as a dust. Also it could be applied to the seed when mixed with water, if applied with a slurry machine.

In 1949 Panogen was introduced into the United States by Panogen, Inc., 117 Hudson Street, New York 13, New York. It may be another step along the line of progress to a perfect seed treating fungicide. It is a liquid and gives off no flying dust to irritate workers. It controls bunt, is inexpensive, and otherwise seems to be a satisfactory seed treatment material for wheat and other cereals.

Leukel (5) concluded from his work, Table 3, that the heavy application of viable bunt spores to the seed of highly susceptible Ulka wheat resulted in extremely high percentages of infection at Aberdeen, Beltsville, Bozeman, and Pullman, and relatively poor control by many of the fungicides, especially at Pullman. The only fungicides that reduced the average of the infection percentages at all the stations to 1 percent or less were Aagrano slurry, Panogen (diluted), Ceresan M slurry, Mercuran A. L., Panogen (concentrated) and K. F. 467. It will be observed that all of these except K. F. 467 were applied in slurry or liquid form.

Ceresan M (dust), copper carbonate, Spergon, Aagrano (dust), Phygon, C & C 640, and Anticarie, more or less in that order of effectiveness, were among the treatments that were fairly satisfactory at several stations where infection in the checks was high. Vancide and Arasan were somewhat less effective. Agrox, Leytosan, Dynacide and L-224, while effective at some stations, failed at others and can hardly qualify as bunticides under conditions of severe infection. Parson's Seed Saver Dust, as has been shown in previous experiments, is almost worthless as a cereal seed treatment.

Leukel stated that it would be difficult to explain satisfactorily the wide differences in bunt control obtained at different stations with some of the fungicides. For example, at Pullman, Bozeman, Aberdeen, and Beltsville, with infection in the checks averaging 97, 83, 93, 5, and 90 percent respectively, Spergon reduced it to less than 5 percent at three of these stations but allowed over 25 percent at Aberdeen. In contrast to this, L-224 reduced infection at Aberdeen and Bozeman to less than half as much as occurred at Pullman. At Urbana with only 22 percent bunt in the checks, Agrox allowed 11 percent infection while at Beltsville, where the check showed 90 percent, Agrox reduced it to 0.8 percent.

It was concluded by Leukel that these and other seeming inconsistencies may be partly explained, perhaps, by the heavy spore load on the seed, combined with extreme variation in the environmental conditions that favor bunt development, fungicidal efficiency or both. He stated that it goes without saying that few farmers would sow seed wheat, carrying a high spore load, and therefore bunt control on the average farm undoubtedly would be more effective than under the above severe experimental conditions.

RESULTS OF EXPERIMENTS

Emergence Tests

It is necessary to denote the names of the various fungicides and other products many times in the tables that follow in this thesis. Abbreviations are used in order to save space.

Table 4. Names of products and the abbreviations used.

Name of Product	Abbreviation
Untreated	Unt.
New Improved Ceresan	NIC
Ceresan M	CM
Copper carbonate	cc
Arasan	Ara.
Spergon	Spg.
Panogen	Pan.
Dichlorodiphenyltrichloroethane	DDT

<u>Fungicidal Treatment of Hot Water Treated Seed</u>. Certified wheat seed of Pawnee variety with a germination of 92 percent was secured from the Kansas State College Agronomy Farm in the fall of 1947. Part of it was treated with hot water as discussed under the heading, Material and Methods. The plan was to study what effect the fungicidal treatment of regular and hot water treated seed would have on the emergence of the plants. The soil moisture content was 10.8 percent on October 15, 11.5 percent on October 29, and 13.1 percent on December 2.

Table 5. The effect of fungicidal wheat seed treatment on the number of plants emerging, 1947.

Name of material	Rate per bu.	% emergence when planted			Average percentage
		Oct. 15	Oct. 29	Dec. 2	
Unt.		70.4	73.2	26.8	56.8
NIC	1/2 oz.	79.2	81.4	53.2	71.2
CM	1/2 oz.	82.2	81.7	45.4	69.7
cc	2 oz.	79.6	75.2	38.6	64.4
Ara.	2 oz.	79.4	81.8	55.1	72.1
Spg.-DDT	2 oz.	79.4	74.7	42.7	65.6

Table 6. The effect of fungicidal seed treatment on hot water treated seed in 1947.

Name of material	Rate per bu.	% emergence when planted			Average percentage
		Oct. 15	Oct. 29	Dec. 2	
Unt.		59.8	58.2	33.0	50.3
NIC	1/2 oz.	72.8	61.9	30.8	55.1
CM	1/2 oz.	72.7	63.2	33.0	56.3
cc	2 oz.	71.4	55.9	33.9	53.7
Ara.	2 oz.	71.8	64.8	33.9	58.8
Spg.-DDT	2 oz.	67.2	54.3	30.5	50.6

One observation made from the above study was that the hot water treatment method which is sometimes used for loose smut control reduced the number of plants emerging 9.1 percent when the seed was planted 6 days after treatment, 18.3 percent when planted 20 days after, and 10.1 percent when planted 54 days after. Late planting also reduced the stand. There was not much difference between the effect of the various fungicides except that Spergon-DDT was almost the same as the check. This may have been due to the effect of the DDT on emergence. The untreated seed gave less emergence than the treated regardless of the kind of fungicide used, except in the December 2 planting of hot water treated seed.

Date of Planting Experiments with Good Seed. The term "good seed" is used to denote certified seed of Pawnee variety which germinated above 92 percent and was healthy in appearance.

Table 7. Wheat seedling emergence, expressed in percent, when good seed was treated with various fungicides and planted October 2 to 15 (customary dates).

Planting date	Unt.	NIC	CM	CC	Ara.	Spg.	Pan.
Oct. 15, 1947	70.4	79.2	82.2	79.6	79.4	79.4	x
Oct. 2, 1948	67.3	69.1	70.5	70.9	70.3	70.0	x
Oct. 10, 1949	65.1	65.1	65.6	66.0	68.2	69.5	65.1
Oct. 15, 1950	84.4	86.0	81.6	78.9	77.3	74.9	83.6
Average	71.7	74.9	75.0	73.9	73.8	73.5	x

Table 8. Wheat seedling emergence, expressed in percent, when good seed was treated with various fungicides and planted October 16 to November 7 (late dates).

Planting date	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
Oct. 29, 1947	73.2	81.4	81.7	75.2	81.8	74.7	x
Oct. 16, 1948	70.4	69.6	70.7	70.9	69.1	68.5	x
Nov. 11, 1949	Wind blew it out due to dry weather.						
Nov. 7, 1950	18.5	21.3	14.9	25.3	28.2	26.7	26.1
Average	52.7	57.5	55.8	57.1	59.7	56.6	x

Table 9. Wheat seedling emergence, expressed percent, when good seed was treated with various fungicides and planted November 8 to February 4 (extremely late dates).

Planting date	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
Dec. 2, 1947	26.8	53.2	45.4	38.6	55.1	42.7	x
Nov. 8, 1948	67.7	67.9	67.2	67.1	68.5	66.8	x
Feb. 4, 1950	67.6	64.4	62.4	67.2	65.3	64.5	64.3
Dec. 14, 1950	26.8	19.9	14.9	27.0	29.9	30.2	24.5
Average	47.2	51.4	47.5	50.0	54.7	51.1	x

Table 10. Average percent emergence from good seed treated with various fungicides as calculated from data given in Tables 7, 8, and 9.

Unt.	NIC	CM	cc	Ara.	Spg.
57.2	61.3	59.4	60.3	62.7	60.4

Seedlings from good seed treated with any one of the fungicides emerged to a greater extent than those from the untreated seed regardless of the date of planting.

The Ceresans were more effective in the October 2 to 15 plantings than in later. This may have been due to the volatile Ceresans losing strength or perhaps injuring the seed during this one and two months of storage.

The results of the tests show that Panogen is equal to the other seed treatment fungicides in effect on emergence. Table 10 shows that Arasan was the most superior fungicide considering emergence and New Improved Ceresan ranked second.

Date of Planting Experiments With Somewhat Inferior Seed. Each year a sample of shriveled, old, or sprouted seed was obtained to compare results with that from using good seed. The so-called "sprouted" seed was not completely sprouted but the germs were enlarged due to starting to sprout in the head in the field. The results from the use of good seed are given in Tables 5, 7, 8, and 9. Tables 4, 10, 11, and 12 are the results of using somewhat inferior seed.

Table 11. Wheat seedling emergence, expressed in percent, when sprouted, shriveled, and one-year-old seed was treated with various fungicides and planted October 2 to 15 (customary dates).

Seed description	Planting date	Unt.	NIC	CM	CC	Ara.	Spg.	Pan.
Germination 94% sprouted 44%	Oct. 2, 1948	56.3	54.3	58.5	53.2	63.2	57.2	x
Germination 94% medium shriveled	Oct. 10, 1949	60.8	61.7	60.8	63.3	61.3	68.3	63.8
One-year-old	Oct. 15, 1950	61.7	73.5	77.7	70.0	77.8	69.7	76.3
Average		59.6	63.2	65.7	62.2	67.4	65.1	x

Table 12. Wheat seedling emergence, expressed in percent, when sprouted, shriveled, and one-year-old seed was treated with various fungicides and planted October 16 to November 7 (late dates).

Seed description	Planting date	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
Germination 94% sprouted 44%	Oct. 16, 1948	52.8	57.3	55.5	52.9	57.6	56.9	x
Germination 94% medium shriveled	Nov. 11, 1949	Blew out due to dry weather						
One-year-old	Nov. 7, 1950	14.4	13.0	13.8	17.2	20.9	17.4	13.5
Average		33.6	35.2	34.7	35.1	39.3	37.2	x

Table 13. Wheat seedling emergence, expressed in percent, when sprouted, shriveled, and one-year-old seed was treated with various fungicides and planted November 8 to February 4 (extremely late dates).

Seed description	Planting date	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
Germination 94% sprouted 44%	Nov. 8, 1948	51.3	50.4	48.5	50.4	57.6	48.0	x
Germination 94% medium shriveled	Feb. 4, 1950	62.7	63.7	60.7	71.3	69.2	65.2	68.5
One-year-old	Dec. 14, 1950	28.5	19.0	24.5	29.5	30.9	30.2	26.8
Average		47.5	44.4	44.6	50.4	52.6	47.8	x

Table 14. Average percent emergence from the somewhat inferior seed treated with various fungicides as calculated from data given in Tables 11, 12, and 13.

Unt.	NIC	CM	cc	Ara.	Spg.
46.9	47.6	48.3	49.2	53.1	50.0

The emergence averages for the untreated plots were below all of the averages for the treated plots in the first two dates of planting. This corresponds to the results with good seed which is given in Tables 7, 8, and 9. The Ceresans were more effective in the earliest plantings than in the later, which is like the results with the good seed.

In comparing Tables 10 and 14 it was observed that every fungicide increased emergence. The average percentage emergence of fungicide treated good seed was 60.8 compared to 57.2 for untreated. This was an increase of 6.3 percent over the untreated check. The average percentage emergence by fungicide treated somewhat inferior seed was 49.6 percent compared to 46.9 for untreated. This was an increase of 5.8 percent over the untreated check. These results showed that there was just as much or more benefit from treating good seed as there was from treating somewhat shriveled, sprouted or one-year-old seed.

The data in Tables 10 and 14 are based on seed planted from October 2 to February 4. Most of the plantings were made much later than the recommended dates for seeding wheat in Kansas. These late plantings were made believing that the results might indicate as to how well treated seed which lays in dry soil for many weeks responds to seed treatment. Nearly all of Kansas wheat is planted the last part of September or the first half of October. The tests which best represent this normal planting time would be those planted October 2 to 15 during the four years the experiments were conducted.

Table 15. The effect of seed treatment on emergence when seed was planted October 2 to 15 for the crop years 1948 to 1951 compared to that planted October 2 to February 4.

Fungicide	Percent increase in emergence when planted Oct. 2 to 15	Oct. 2 to Feb. 4
Untreated	x	x
New Improved Ceresan	6.9	4.6
Ceresan M	7.5	3.5
Copper carbonate	5.3	5.2
Arasan	7.8	11.2
Spergon	5.8	6.1
Panogen	7.5	8.1

Data in Table 15 indicates that the Ceresans are practically as effective as Arasan when seed is planted during the first half of October. The lesser emergence when plantings were made later may have been due to the Ceresans becoming less effective when stored on the seed or the possibility that when the Ceresans were on the seed this long and under such conditions they became damaging to some of the seed so that some of the benefits were offset. A check of Tables 7 to 13 shows that most of the lowering of germination due to seed treatment with the Ceresans occurred in plantings of the somewhat sprouted and one-year-old seed when the chemicals were on the seed from one to four months and planted November 8 to February 4, which was late.

Experiments With Farmers' Seed and the Effect of Soil Moisture Percentage on Emergence. Seven samples of seed were obtained from farmers in order to have a greater number of samples for testing and to have seed which was grown in a location other than Riley County. These came from Coffey, Elk, Montgomery, Wilson, Neosho, and Labette counties. This seed was of the 1948 harvest.

Table 16. The effect of seed treatment on emergence when seven samples of farmers' seed were used in 1948. From 0 to 76 percent of the kernels in the samples had slightly sprouted in the field due to wet weather.

Planted	Soil moisture percentage	Untreated	Copper carbonate	Ceresan M
Oct. 16, 1948	11.1	48.7	50.0	53.6
Nov. 8, 1948	14.7	42.9	43.2	46.2
Average		45.8	46.6	49.9

Nine samples were obtained from farmers in Harper, Reno, Allen, Lyon, Barton, Haskell, Nemaha, Cheyenne, and Mitchell counties in 1949. Wheat seed in general was shriveled some this particular year due to the wet season and diseases. These samples varied from 0 to 19 percent shriveled kernels.

Table 17. The effect of seed treatment on emergence when nine samples of farmers' seed were used in 1949. Most samples had 0 to 19 percent shriveled kernels.

Planted	Soil moisture percentage	Untreated	Copper carbonate	Ceresan M
Oct. 19, 1949	9.7	49.9	51.7	51.4

The results from these sixteen samples of seed planted two different years showed that treating the seed increased emergence consistently. Tables 16 and 17 correspond in results to that obtained from the use of good and somewhat inferior seed as shown in previous tables.

Only Ceresan M and copper carbonate were used in these tests because Ceresan M was used by wheat growers more than any other seed treatment fungicide and copper carbonate was used more for treating wheat seed than any other non-volatile fungicide.

Another observation from Tables 16 and 17 was that a difference of between 9.7 percent soil moisture and 14.7 percent apparently did not influence the effect of the fungicides. Soil moisture samples were taken at the time of planting for all of the tests mentioned in this thesis. The widest range of moisture content was that given in Tables 16 and 17. In no case throughout all the experiments was there an indication of a significant difference due to a variation in soil moisture percentage.

Effect on Emergence of Storing Treated Seed. Some of the treated and untreated seed that was used to get the results for Tables 5, 7, 8, and 9 was stored and some planted each year to find out what affect seed treatment fungicides would have on stored seed. Sometimes farmers hold seed over to be planted in later years.

Table 18. Wheat seedling emergence, expressed in percent, when certified Pawnee seed of the 1947 crop was treated October 13, 1947, and stored.

Planted	Unt.	NIC	CM	cc	Ara.	Spg.-DDT
Oct. 15, 1947	70.4	79.2	82.2	79.6	79.4	79.4
Oct. 16, 1948	59.9	64.3	62.5	63.3	64.3	48.8
Oct. 10, 1949	50.7	40.9	45.7	49.6	44.3	33.1
Oct. 13, 1950	45.5	38.0	38.0	39.7	42.7	30.5

Table 18 shows that the longer the seed treatment fungicides were on the seed the more emergence was reduced. In fact when they were on the seed more than two years the treated seed produced less plants than the untreated seed.

Table 19. Wheat seedling emergence, expressed in percent, when three different lots of treated good seed, which had been stored, were used.

Seed Description	Fungicide on Seed	Planted	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
1947 Pawnee	3 years	10-13-50	45.5	38.0	38.0	39.7	43.7	30.5	x
1948 Pawnee	2 years	10-15-50	70.1	62.9	63.9	70.8	67.9	64.4	x
1949 Pawnee	1 year	10-15-50	73.2	66.8	66.0	74.4	78.8	76.2	72.3

In Table 19, when the fungicides were on the seed for over two years, most all counts were below the untreated. When they were on one year those of the mercury-volatile group, namely, New Improved Ceresan, Ceresan M, and Panogen, were below the untreated. However, with the seed which gave the results listed in Table 18 even after the fungicide was on the seed a year, the treated emerged better than the untreated. This 1947 seed responded greatly to seed treatment which could account for the difference in results.

Effect of Dosage of Ceresan M and Panogen on the Seed. To study the effect of the dosage of Ceresan M and Panogen on the seed, some grain of Red Chief variety was used. Bunt was applied artifically to the seed. The seed was treated with various fungicides on September 8, 1949. Samples of the untreated and treated seed were taken periodically to the State Seed Laboratory, Manhattan, Kansas, for germination tests.

Tabel 20. Percent germination as a result of various dosages of Ceresan M and Panogen on bunted Red Chief seed.

Material	Oz. per bushel	Germination tests were completed on these dates: 9-12-49	10-20-49	5-16-50	10-13-50
Ceresan M	1/3	92	93	94	92
Ceresan M	1/2	86	88	89	89
Ceresan M	1	75	73	77	70
Ceresan M	1 1/2	58	56	63	51
Panogen	1/4 fl.	95	98	91	94
Panogen	1/2 fl.	95	96	97	96
Panogen	3/4 fl.	95	96	96	97
Panogen	1 fl.	98	97	93	94
Panogen	1 1/4 fl.	95	93	93	96
Untreated and not bunted		94	92	92	91

Table 20 shows that perhaps one ounce and definitely 1 1/2 ounces of Ceresan M per bushel of seed reduces germination in a seed germinator. The seed was apparently injured the first few days the Ceresan M was on the seed because there was no further reduction in germination at later dates of testing. The seed placed between the blotters in the seed germinator may not have allowed the Ceresan fumes to escape as they perhaps do when on seed in the soil.

Any amount of Panogen from 1/4 of a fluid ounce to 1 1/4 fluid ounces per bushel of seed did not reduce germination. All amounts of Panogen used increased germination compared to the untreated lot of seed.

Effect of Seed Treatment on Yields. To determine how much effect the number of plants at emergence would have on the number of heads produced, a count of heads was made in the December 2, 1947, planting. The emergence count was made April 6, 1948, and the head count was made June 24, 1948. This plot was used because of the much larger number of plants in the treated rows.

Table 21. The effect of seedling stand on number of heads produced when Pawnee wheat was planted at the rate of 1 1/4 bushels per acre.

Treatment	No. seedlings	No. heads
Untreated	268	851
N. I. Ceresan	532	1258
Ceresan M	454	1078
Copper carbonate	386	1023
Arasan	551	1244
Spergon-DDT	427	1160

Table 21 shows that the number of plants at seedling stage definitely affects the number of heads produced if there is as great a difference in number of seedlings as there was in this experiment.

In 1951 there was practically no damage to one of the plots. The soil looked uniform, there had been no noticable washing of the soil and there was no rodent or bird damage. Therefore, yields were taken on this plot. The seed was treated October 11, 1950, and was planted October 15, 1950, in replicated 10-foot rows. The rate of seeding was 1 1/4 bushels per acre. The seed was certified Pawnee variety. The plants were counted November 1, 1950, and the grain was harvested July 20, 1951.

Table 22. The effect of wheat seed treatment on yields in 1951.

	Unt.	NIC	CM	cc	Ara.	Spg.	Pan.
Number of seedlings	617	735	777	700	778	697	763
Yield in grams	559	652	745	641	750	641	755
Yield in bu. per acre	22.4	26.1	29.8	25.6	30.0	25.6	30.2

The plots with the highest number of plants made the highest yields, in general. The untreated replications had fewer plants and lower yields than any of the treated.

Bunt Control Tests

Experiments were conducted from 1947 to 1951 to determine the value of various fungicides in controlling stinking smut (bunt).

Table 23. Percent of bunt as a result of seed treatment with various fungicides compared to no treatment.

Fungicide	Oz. per bu. seed	11-4-47	12-2-47	11-8-48	10-26-49	11-14-50
Untreated		81.4	23.7	77.5	19.2	88.8
Ceresan M	1/2	5.0	.5	0	.4	0
Ceresan M	1			0	0	0
N. I. Ceresan	1/2	.9	.2	0	2.1	0
N. I. Ceresan	1			0	.2	.3
Copper carbonate	2	.7	.2		0	0
Arasan	2	7.1	13.3	1.5	.7	1.3
Spergon	2	1.8	.3	.8	.2	.8
Ch. Hydro. #4	2				0	0
MTH Control N-3358	2			.5	.5	.3
NNP	2			0	0	0
KF Deleware	1/2				.8	0
Panogen	3/4 fl.				.2	0
Panogen	1 1/2 fl.				0	0
Phygon-XL	2			1.3	2.0	0
FW	2.4				1.9	3.8
Mercan A	1			62.5		20.5
Mercan B	1			46.3		27.5
Lindane (w. p.)*	3					39.0
Aldrin (e. c.)**	1 1/2					47.0
Aldrin (w. p.)*	3					57.5
Dieldrin (e. p.)**	1 1/2					70.0
Dieldrin (w. p.)*	3					76.3

*Wettable powder **Emulsifable concentrate

From the above results the following products and rates per bushel of seed would be considered satisfactory to use under farm conditions for bunt control: Ceresan M 1/2 ounce, Ceresan M 1 ounce, New Improved Ceresan 1/2 ounce, New Improved Ceresan 1 ounce, copper carbonate 2 ounces, Spergon 2 ounces, Chlorinated Hydrocarbon no. 4 two ounces, MTH Control N-3358 two ounces, N-Nitroso-Phthalimidine 2 ounces, KF Deleware 1/2 ounce, Panogen 3/4 ounce, Panogen 1 1/2 ounces, Phygon-XL 2 ounces, and FW 2.4 ounces. Wheat seed completely covered with bunt, like this seed was, should not be used for planting farm fields. These products listed as satisfactory would generally give complete control of bunt when used every year under farm conditions.

DISCUSSION

Leukel (5) showed that when bunted Ulka wheat was seeded in sterilized soil, two months and six months after treatment, none of the fungicidal seed treatments used had any appreciable effect upon germination. This could mean that the Ulka wheat seed used was highly free of damping-off organisms, that only adverse growing conditions enables the organisms to reduce emergence, or that most of the reduction in emergence is due to soil-borne organisms. It may be that the Kansas seed the writer used contained more organism load or that the soil in the nurseries and at the Agronomy Farm at Kansas State College contained injurious organisms. The writer got an average increase in emergence of 6.3 percent with good certified Pawnee seed and an average increase of 5.8 percent with average somewhat shriveled, sprouted, and one year old seed. These results were obtained with various lots of seed planted in the years 1947, 1948, 1949, and 1950 in Kansas.

Leukel (5) stated that New Improved Ceresan, Ceresan, Ceresan M, copper carbonate, basic copper sulfate, Arasan, Spergon, Phygon, and a number of less commonly used fungicides, if properly applied, will control bunt satisfactorily where soil infestation does not occur. He also stated that some of these materials are inferior to the organic mercurials in eliminating organisms that are borne within the seed, although some of them serve as excellent seed protectants. The Ceresans mentioned above are organic mercurials. This information given by Leukel concerning bunt control corresponds with the results that this writer obtained.

The average increases in emergence from use of the various fungicides when planting was done at the usual time, the first part of October, are given in Table 15. None of the materials gave greater emergence than Ceresan M except Arasan, which gave only three tenths of one percent more and this was insignificant. The amount of Ceresan M necessary to treat a bushel of wheat seed costs only 4 cents and the amount of Arasan needed to treat a bushel costs 25 cents. Ceresan M gave an increase in emergence of 7.5 percent. This means that 55.5 pounds of treated seed will produce as many plants as 60 pounds of untreated. This is a saving of approximately 18 cents worth of wheat seed by using the Ceresan M which costs only 4 cents. This would mean that if all farmers of Kansas would treat their wheat seed they could plant at least 500,000 bushels less seed each year which would be a saving of $900,000 annually. The range of increase in emergence from using Ceresan M was from 0 to 14 percent. It would certainly be important to treat lots of seed which give an increase of 7.5 percent or more because a stand of wheat reduced from approximately 7 to 14 percent would produce less yield as indicated in Table 22.

If there was no effective fungicide available for the control of bunt, in a matter of perhaps 10 or 15 years the loss due to bunt in Kansas would probably amount to from 5 to 15 percent. A loss of 10 percent would be a loss of $35,000,000 annually to Kansas wheat growers at the present wheat price. Therefore, it is very important that the seed treatment materials used be effective in controlling bunt. Table 23 shows that Ceresan M and some of the other products are very effective in controlling bunt.

An ideal seed treatment material would be one which would: (1) increase emergence to the greatest extent possible, (2) control bunt effectively, (3) be inexpensive, (4) not result in flying dust or otherwise harm workers, (5) not poison livestock, (6) not injure seed when too much fungicide is used or when the treated seed is stored, (7) flow from the drill properly, (8) not be rendered inefficient by ordinary environment such as freezing temperatures, (9) be available in small as well as large quantities, and (10) not make it necessary to delay seeding after it is on the seed. Ceresan M is objected to because of items 4, 5, 6, 10, and sometimes item 8 when used mixed with water in a slurry machine. However, the manufacturer states that freezing can be prevented by adding alcohol anti-freeze to the mixture. Panogen is objected to because of items 5, 6, 9, and perhaps 10. The smallest amount of Panogen one can buy is 5 gallons which is enough to treat over 700 bushels of seed. This quantity is too large to be used by most farmers. Whether or not one can plant the seed immediately after it has been treated with Panogen without impairing its effectiveness has not yet been determined. New Improved Ceresan has about the same characteristics as Ceresan M but is more irritating to workers and cannot be mixed readily with water in a slurry machine. Copper carbonate is sometimes criticized because of item 7. It sometimes tends to bind the seed together in the drill box. It did not increase emergence as much as Ceresan M and costs slightly more. Arasan is criticized on items 3, 4, and perhaps on item 2. Spergon is objected to because of items 1, 3, and 4. In considering all items, Panogen or Ceresan M are the most practical to use for treating wheat seed. Chemical companies are trying to produce products which will have all of the ten characteristics just given. They probably will succeed in a few years.

SUMMARY

Emergence Tests

Wheat seed which had been hot water treated by the customary method to control loose smut, allowed to dry, and then divided into lots and treated with New Improved Ceresan, Ceresan M, copper carbonate, Arasan, and Spergon-DDT had the same effect on emergence as if the seed had not been hot water treated.

Seed which had enlarged germs due to starting to sprout in the field, seed which was somewhat shriveled, and one-year-old seed, responded to seed treatment with New Improved Ceresan, Ceresan M, copper carbonate, Arasan, Spergon, and Panogen with increased emergence as did healthy appearing seed.

Seedlings from all of the above seed treated with any one of the fungicides used emerged to a greater extent than those from untreated seed regardless of the date of planting. The following percent increases in emergence from use of seed treatment materials was obtained when wheat was planted periodically from October 2 to February 4, based upon data in Tables 5 to 14, inclusive:

New Improved Ceresan	4.6
Ceresan M	3.5
Copper carbonate	5.2
Arasan	11.1
Spergon	6.0
Panogen	8.1

The wheat which was planted from October 2 to 15, which is near the recommended dates for planting wheat in Kansas, gave the following percent increases in emergence from use of seed treatment materials as computed from Tables 7 and 11:

New Improved Ceresan	6.9
Ceresan M	7.5
Copper carbonate	5.3
Arasan	7.8
Spergon	5.8
Panogen	7.5

A comparison of the figures in the above table with those in the preceding table shows that the best results with the Ceresans are obtained when either they are put on the seed only a few days before planting or when the treated seed is not planted extremely late.

A difference of between 9.7 percent and 14.7 percent soil moisture did not influence the effect of the above six seed treatment fungicides on emergence of wheat plants.

Seed treated with New Improved Ceresan and Ceresan M, stored for one year, and planted out-of-doors, gave greater emergence than the untreated in the case of one lot of seed but not in the case of another. In the same tests copper carbonate, Arasan, and Spergon treated seed gave better emergence than the untreated in both cases. When the Ceresans were on the seed 2 and 3 years the emergence was always below the untreated approximately 10 to 20 percent. In the same tests copper carbonate and Arasan were below the untreated approximately 0 to 10 percent and Spergon was below approximately 12 to 30 percent. The seed was stored in paper bags inside of galvanized iron boxes.

In another test, samples of stored treated seed were taken periodically to the State Seed Laboratory for germination tests. In these tests when 1/2 or 1/3 of an ounce of Ceresan M per bushel of seed was used the germination was not lowered when the seed was stored one year. However, in the case when one ounce of Ceresan M was used the germination was lowered approximately 20 percent in 4 days. When 1 1/2 ounces were used the germination was lowered approximately 35 percent in 4 days. Storage for one year did not tend to lower it any more. In this same test Panogen improved the germination slightly when on the seed one month and also resulted in better germination than the untreated when on the seed one year. The Panogen rate commercially recommended is 3/4 of a fluid ounce per bushel of wheat seed but the rates used were 1/4, 1/2, 3/4, 1, and 1 1/4 ounces per bushel. None of these rates lowered germination even when on the seed 12 months.

Bunt Control Tests

The results obtained showed that the following products of those tested would control stinking smut (bunt) under farm conditions: Ceresan M 1/2 ounce per bushel of wheat seed, Ceresan M 1 ounce, New Improved Ceresan 1/2 ounce, New Improved Ceresan 1 ounce, copper carbonate 2 ounces, Spergon 2 ounces, Chlorinated Hydrocarbon no. 4 two ounces, MEH Control N-3358, two ounces, N-Nitroso-Phthalimidine 2 ounces, KF Deleware 1/2 ounce, Panogen 3/4 fluid ounces, Panogen 1 1/2 fluid ounces, Phygon-XL 2 ounces, and FW 2.4 ounces. If wheat was free of bunt and Arasan applied to the seed each year probably bunt would be prevented satisfactorily.

The following fungicides did not give sufficient bunt control in the tests to be considered satisfactory for farm use: Mercan A one ounce per bushel, Mercan B one ounce, Lindane 3 ounces of wettable powder, Aldrin, and Dieldrin. Aldrin and Dieldrin were used at the rate of 3 ounces of wettable powder per bushel of grain and also at the rate of 1 1/2 ounces of emulsifible concentrate. Lindane, Aldrin, and Dieldrin reduced stands considerably.

ACKNOWLEDGEMENT

The author wishes to express gratitude to Dr. Earl D. Hansing, major instructor, for his guidance during the course of the research for this thesis and for his suggestions on writing it. Also the author wishes to thank Dr. Stuart M. Pady, Head of the Department of Botany and Plant Pathology, Kansas State College, for his advice concerning the preparation of this thesis.

REFERENCES

(1) Bamberg, R. H.
"Seedling Blight of Wheat in Minnesota."
Plant Disease Reporter, 20(12): 197, July 1, 1936.

(2) Brentzel, X. E.
"Effects of Blights and Other Damage on Durum and Hard Wheat Seed". North Dakota Station Bulletin 296, pp. 9-14, 1941.

(3) Call, L. E.
"Fifth Biennial Report of the Director of the Kansas State College Agricultural Experiment Station." Kansas State College, Manhattan, Kansas. July 1, 1928 to June 30, 1930.

(4) King, Claude L.
"Extension Plant Pathologist's Annual Report for 1951."
Extension Service, Kansas State College, Manhattan, Kansas. 1951.

(5) Leukel, R. W.
"Cooperative Seed-Treatment Tests on Small Grains in 1951."
Plant Disease Reporter, 35(10): 447, October 15, 1951.

(6) Mackie, W. W., and Briggs, F. N.
"Fungicidal Dusts For the Control of Smut." Science N. S. 52: 540-541. 1920.

(7) Melchers, L. E.
"Bunt Control in Kansas." Contribution No. 496, serial No. 411, Department of Botany, Kansas State College, Manhattan, Kansas. June 1950.

(8) Tervet, Ian W.
"Survey of Microflora of Wheat Seed from Minnesota, North Dakota, and South Dakota." Plant Disease Reporter, 28(23): 738, August 1, 1944.

(9) Wallin, J. R.
"Seed and Seedling Infection of Barley, Bromegrass and Wheat by Xanthomonas translucens var. cerealis." Phytopathology, 36(6): 446-457, 1946.

THE EFFECT OF FUNGICIDAL SEED TREATMENT ON WHEAT PLANT EMERGENCE AND BUNT CONTROL

by

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of Agriculture and Applied Science, 1932

AN ABSTRACT OF A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Botany and Plant Pathology

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1953

PURPOSE

The purposes of this investigation were to determine the effect of several seed treatment fungicides on the amount of wheat seedling emergence, if increased emergence would be sufficient to justify treating the wheat seed independent of bunt control, and how effective the various fungicides would be in controlling bunt.

METHODS AND RESULTS

Emergence Tests

Wheat seed was treated with several fungicides to determine the effect on seedling emergence. Tests were made for four years. In the 1947 and 1950 plantings the rows were 10 feet long and 200 seeds were planted per row. In the 1948 and 1949 plantings, the rows were 8 feet long and 150 seeds were planted per row. Five replications of each treatment were used.

In 1947, Pawnee wheat seed treated by the hot water method for loose smut control was also treated with the various fungicides. The same wheat seed which had not been subjected to hot water was likewise treated with various fungicides. Plantings were made on three different dates. Hot water treatment of the seed lowered emergence an average of 14 percent. There was not much difference in the effect of the various fungicides on emergence. An exception was that Spergon - DDT was almost the same as the check, which may have been due to the effect of the DDT on emergence. The untreated seed gave less emergence than the treated regardless of the kind of fungicide or whether hot water treated or not.

The December 2 planting of hot water treated seed showed no increase from fungicidal seed treatment except in the case of Arasan. This late planting did not emerge until spring so that the fungicides were on the seed in the soil during this time and it may be that the sprouts would start growing a little due to warm days in the winter and then would be subjected to a freeze. This obstacle to good growth might have caused the seed treatment materials except Arasan to have a detrimental effect on the sprouts and consequently on germination.

From the four years of seed treatment tests with good certified Pawnee seed the fungicides had the following effect on emergence:

Fungicide	% Emergence	% Emergence Increase
Untreated	57.2	x
New Improved Ceresan	61.3	7.2
Ceresan M	59.4	3.8
Copper carbonate	60.3	5.4
Arasan	62.7	9.6
Spergon	60.4	5.6

The fungicide, Panogen, became available so that it was tested only in 1949 and 1950. It compared favorably with the Ceresans in emergence results. Good seed treated with any one of the fungicides emerged to a greater extent than the untreated seed regardless of the date of planting. There was less difference between emergence from the untreated seed and that from treated seed in the plantings made the first part of October than in the later plantings, probably due to higher soil temperatures being more favorable for rapid germination and growth of the seedlings.

For the years 1948, 1949, and 1950 somewhat inferior seed was obtained each fall to compare seed treatment results with that from using good seed. Seed which had 44 percent enlarged germs, due to wet conditions in the field before harvest, was used in 1948. Seed which was somewhat shriveled was used in 1949. That used in 1950 was one year old seed. All of these samples had a laboratory germination of more than 90 percent.

The emergence averages for the untreated plots for the three years were below all of the averages for the treated plots in the first two dates of planting of this somewhat inferior seed. This corresponds to the results with good seed. However, a greater difference between untreated and treated was evident in the first part of October plantings of somewhat inferior seed than in the later plantings, which was just the reverse of the results with good seed.

The following are the results of the effect of the various fungicides on emergence when the somewhat inferior seed was used:

Fungicide	% Emergence	% Emergence Increase
Untreated	46.9	x
New Improved Ceresan	47.6	1.5
Ceresan M	48.3	3.0
Copper carbonate	49.2	4.8
Arasan	53.1	13.2
Spergon	50.0	6.6

The fungicide, Panogen, was available only during the crop years 1949 and 1950. Seed treated with it gave greater emergence than that treated with the Ceresans and a smaller amount than that treated with Arasan.

In comparing the over-all averages of the results given as data on the somewhat inferior seed with that of the good seed, it can be noted that every fungicide increased emergence. The average percentage emergence of fungicide-treated good seed was 60.8 compared to 57.2 for untreated. This was an increase of 6.3 percent over the untreated check. The average increase by the fungicides on the somewhat inferior seed was 5.8 percent over the untreated check. Based on these results, it is just as important to treat good looking seed as it is to treat field sprouted, shriveled, or one-year-old seed.

The data in the foregoing two tables in this abstract are based on seed planted from October 2 to February 4. Consequently most of the seed was planted much later than the recommended dates for seeding wheat in Kansas. The following is a summary of the data from the tests planted October 2 to 15 for the four years, which would be the customary and desirable planting dates:

Fungicide	% Emergence	% Emergence Increase
Untreated	65.5	x
New Improved Ceresan	70.0	6.9
Ceresan M	70.4	7.5
Copper carbonate	69.0	5.3
Arasan	70.6	7.8
Spergon	69.3	5.8
Panogen	70.4	7.5

This indicates that the Ceresans and Panogen are practically as effective as Arasan when seed is planted during the first half of October.

To have a greater number of samples of seed for testing the fungicides and to have seed from different locations in Kansas, seven samples were obtained from farmers in 1948. Zero to 76 percent of the kernels in these samples were slightly sprouted due to wet conditions in the field before harvest. The following were the average percentages of emergence and emergence increase due to seed treatment:

Fungicide	% Emergence	% Emergence Increase
Untreated	45.8	x
Copper carbonate	46.6	1.7
Ceresan M	49.9	8.9

This included a planting made October 16 and one made November 8. On October 16 the soil moisture percentage was 11.1 and on November 8 it was 14.7. From the results obtained this difference in moisture percentage did not influence the effect of the fungicides.

Nine samples of farmers seed were obtained in 1949. Most of the samples were grain which was somewhat shriveled. The following were the average percentages of emergence and emergence increase due to seed treatment.

Fungicide	% Emergence	% Emergence Increase
Untreated	49.9	x
Copper carbonate	51.7	3.6
Ceresan M	51.4	3.0

The data given in the above two tables is similar to the information obtained in the tests discussed previously in this abstract in which somewhat inferior seed and good seed were compared.

A study was made of the effect on emergence of storing treated seed. Some seed originally treated in 1947 was kept and some of it planted each year for four years. The results were that the longer the seed treatment fungicides were on the seed the less the emergence from the seed. In fact, when they were on the seed more than two years the treated seed produced less plants than the untreated seed. Another study was made by planting 1947 seed which had been treated three years, 1948 seed treated two years, and 1949 seed treated one year. In this test when the fungicides were on the seed more than two years most all were below the untreated in percentage of emergence. When they were on one year, those of the mercury-volatile group, which included New Improved Ceresan, Ceresan M, and Panogen, were below the untreated.

To study the affect of dosage of Ceresan M and Panogen on the seed, some seed of Red Chief variety was used. Samples were taken periodically to the State Seed Laboratory for germination tests. The seed was treated September 8, 1949, and taken to the Laboratory September 12 and October 20 of 1949 and May 16 and October 13 of 1950. One ounce and especially 1 1/2 ounces of Ceresan M per bushel of seed reduced germination. The seed was apparently injured the first few days the Ceresan M was on the seed because there was no further reduction in germination at later dates of testing. Any amount of Panogen from 1/4 of a fluid ounce to 1 1/4 fluid ounces per bushel of seed did not reduce germination. All amounts of Panogen used increased germination compared to the untreated seed.

In 1951 there was practically no damage to one of the plots. The soil looked uniform, there had been no noticeable washing of the soil and there was no rodent or bird damage. Consequently yields were taken on this plot. The seed was treated October 11, 1950, and was planted October 15, 1950, in replicated 10-foot rows. The plants were counted November 1, 1950, and harvesting was done July 20, 1951. The following results were obtained:

	Unt.	NIC	CM	CC	Ara.	Spg.	Pan.
Number of seedlings	617	735	777	700	778	697	763
Yield in bu. per acre	22.4	26.1	29.8	25.6	30.0	25.6	30.2

The seeding above was at the rate of 1 1/4 bushels per acre which is the usual recommended rate for eastern Kansas. The plots with the highest number of plants made the highest yields, in general. The untreated replications had fewer plants and lower yields than any of the treated. The untreated produced approximately 8 bushels per acre less than the treated. It may be that this large increase in yield was obtained because the dry, cold fall of 1950 may have prevented good tillering in wheat planted this late. However, the conditions were not too different from those occurring often in Kansas.

Bunt Control Tests

Experiments were conducted from 1947 to 1951, to determine the value of various fungicides in controlling stinking smut (bunt). Powdered bunt was applied to the seed so that the seed was completely covered. Then the various fungicides were applied to lots of the seed. The treated seed was measured out so that there were approximately 200 seeds to a ten-foot row. Four replications of rows were planted. The plantings were made in the Botany and Plant Pathology Department Nursery, Kansas State College, Manhattan, Kansas.

Percentages of bunt as a result of seed treatment with various fungicides compared to no treatment.

Fungicide	Oz. per bu. seed	Seed Planted on these dates 11-4-47	12-2-47	11-8-48	10-26-49	11-14-50
Untreated		81.4	23.7	77.5	19.2	88.8
Ceresan M	1/2	5.0	.5	0	.4	0
Ceresan M	1			0	0	0
N. I. Ceresan	1/2	.9	.2	0	2.1	0
N . I. Ceresan	1			0	.2	.3
Copper carbonate	2	.7	.2	[illegible]	0	0
Arasan	2	7.1	13.3	1.5	.7	1.3
Spergon	2	1.8	.3	.8	.2	.8
Ch. Hydro. #4	2				0	0
MTH Control N-3358	2			.5	.5	.3
NNP	2			0	0	0
KF Deleware	1/2				.8	0
Panogen	3/4 fl.				.2	0
Panogen	1 1/2 fl.				0	0
Phygon-XL	2			1.3	2.0	0
FW	2.4				1.9	3.8
Mercan A	1			62.5		20.5
Mercan B	1			46.3		27.5
Lindane (w. p.)*	3					39.0
Aldrin (e. c.)**	1 1/2					47.0
Aldrin (w. p.)	3					57.5
Dieldrin(e. p.)	1 1/2					70.0
Dieldrin(w. p.)	3					76.3

*Wettable powder **Emulsifable concentrate

From the above results the following products and amounts per bushel of seed would be considered satisfactory to use under farm conditions for bunt control: Ceresan M 1/2 ounce, Ceresan M 1 ounce, New Improved Ceresan 1/2 ounce, New Improved Ceresan 1 ounce, copper carbonate 2 ounces, Spergon 2 ounces, Chlorinated Hydrocarbon #4 two ounces, MTH Control N-3358 two ounces, N-Nitroso-Phthalimidine 2 ounces, KF Deleware 1/2 ounce, Panogen 3/4 of a fluid ounce, Panogen 1 1/2 ounces, Phygon-XL 2 ounces, and FW 2.4 ounces. Wheat seed completely covered with bunt like this seed was should not be used for planting farm fields. These products listed as satisfactory would undoubtedly give complete control of bunt when used every year on ordinary farm seed.