PRELIMINARY STUDIES OF SORGHUM HEAD MOLD AND ITS CONTROL

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By

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Bachelor of Science

Oklahoma Agricultural and Mechanical College

Stillwater, Oklahoma

1949

Submitted to the Department of Botany and Plant Pathology

Oklahoma Agricultural and Mechanical College

In Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

1951

APPROVED:

Chairman, Thesis Committee

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ACKNOWLEDGEMENTS

The writer wishes to express his gratitude to Dr. H. C. Young, Jr., for constructive criticism during the course of study and in the preparation of the manuscript. Acknowledgement also is due J. B. Sieglinger for providing the experimental plots, C. E. Marshall for advise on statistical problems, and W. D. Guthrie for assistance in estimating insect damage.

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INTRODUCTION

Approximately 80 percent of the grain sorghum produced in the United States is grown in Western Oklahoma, Southwestern Kansas, and Northwestern Texas. The ability of sorghum to produce a satisfactory crop under conditions of limited rainfall, and the ability to withstand the hot, dry winds of summer make it especially adaptable as a cash crop in that area. Production figures indicate that 1,014,000[1] acres were planted to grain sorghum in Oklahoma in 1950, yielding $21,091,000[2]. Production in this quantity means that grain sorghum is of considerable importance in the agriculture of Oklahoma.

As with many other field crops, improvements in the adaptibility, yield, and disease resistance of sorghum have been brought about by breeding and selection. Sorghum belongs to the "often cross-pollinated group" (5 to 50 percent natural crossing), of farm crops[3], but the essential features of most breeding programs for sorghum improvement are the same as for the normally self-pollinated group. It is necessary, however, to control pollination by some means, either by bagging the panicles or by isolation, in order to maintain selfed lines or varietal purity.

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[1] U. S. Department of Agriculture, Crop Production, Annual Summary. p. 59. 1950.

[2] U. S. Department of Agriculture, Agricultural Prices, Season Average Prices and Value of Production. p. 10. 1949 and 1950.

[3] Hayes, H. K. and R. J. Garber. Breeding Crop Plants. p. 248-249, 2nd edition McGraw-Hill Book Company, Inc., New York. 1927.

The practice of bagging the sorghum heads has been adopted by most plant breeders because of space limitations. However, the bags, in addition to controlling pollination, may also serve as incubation chambers for growth of certain fungi.

The heads, under the bags, often become moldy. Mold growth varies on these heads from a light scattered spotting to complete coverage (Figure 1). In many cases the spikelets and kernels are held tightly together by this growth so that the head becomes quite rigid. When the mold growth starts soon after the head is bagged, as it often does, the anthers may become molded so quickly that pollen is not shed, or the style and stigma may be covered or destroyed before pollination. In cases where the mold continues to develop, or if mold growth starts at a later time, further damage is caused by the head becoming so covered and encrusted with mycelium that thrashing is extremely difficult. In any case, seed yield is usually reduced appreciably. It has been noted in the breeding program at Oklahoma A. & M. College that seed produced on moldy heads may be low in germination, or if the seed does germinate may produce seedlings low in vigor. Additional damage to bagged sorghum heads may be caused by various insects, including the corn leaf aphid, *Aphis maidis* Fitch, and the corn earworm, *Heliothis armigera* (Hbn). A study of the insects involved, and their control, has been made recently by Guthrie[4].

The appearance of moldy and insect infested heads following the bagging of sorghum has harassed the plant breeder and commercial seedsman

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[4] Guthrie, W. D. The control of the corn earworm and corn leaf aphid on bagged sorghum heads. A Masters degree thesis on file. Oklahoma A. & M. College Library. Stillwater, Oklahoma 1950.

Fig. 1. Head mold of sorghum (left) compared with a clean sorghum head (right).

alike. Suitable control methods would not only add speed and efficiency to the breeding program, but would assure the seed producer a high yield of quality seed.

Preliminary studies have indicated that no one organism is responsible for this moldy condition. Isolations from diseased heads have yielded species of several different genera of fungi. All of these species are known to be predominantly saprophytic in nature, and none has appeared with any degree of regularity in the isolations. The appearance of the heads themselves indicates that this moldy condition may be brought about by the growth of many saprophytic fungi, singly or in various combinations.

The purpose of this study was to determine the organisms responsible for "molded" heads; to follow the course of mold development, and to devise, if possible, a suitable control.

MATERIALS AND METHODS

Isolations from moldy sorghum heads were made on either or both of two media; potato-dextrose agar, and potato-dextrose agar acidified with 10 drops of 50 percent lactic acid to each 250 cc of media. Examination of the cultures and tentative identification of the resulting colonies were made after a 7 to 10 day incubation period at room temperature.

For several reasons the use of protectant fungicides seemed the most logical method of control. However, there was no precedent for the use of any particular fungicide or concentration on these saprophytic molds, and since preliminary isolations had implicated a number of causal fungi, several fungicides including representatives of the copper, sulphur, organic and mercuric groups were tested at various concentrations and in various ways. For the sake of brevity and clarity these materials and concentrations are listed in tables 1, 2, and 3. Since insect control is equally as essential as mold control, combinations of certain fungicides and insecticides were tested. These combinations also are listed in tables 1 and 2.

The materials were used in several ways. In one experiment half of the plants were treated by applying the materials directly to the head as a dust just prior to bagging, and half of the plants were treated by applying the dust to the inside of the bag immediately before it was placed on the head. In another experiment the materials were applied directly to the heads as a spray. In still another test the bags were dipped in an aqueous suspension of the various materials used for a period of 15 minutes, after which they were dried and applied to the sorghum heads. In all cases care was taken to insure that the same amount of material was applied to each head or to each bag, according to the method of application. The bags used in these experiments were 20 pound wet strength craft paper with water proof seams. The bags were supplied by the Agronomy Department, Oklahoma A. and M. College, and are the same as those used in the sorghum breeding program.

The treatments were made and the bags applied when the first anthers were beginning to emerge from the florets. That is the normal time for the bags to be applied in the breeding program. The leaves at the first node below the heads of these plants were removed to allow a snug fit for the bags, which is the usual procedure followed in the breeding program.

The dust and spray experiments were applied on the variety Redland at the Oklahoma A. and M. College Experimental Farm, Perkins, Oklahoma.

Table 1. The fungicides and insecticides, and the concentration of active ingredient in each, that were applied directly to the sorghum heads, or to the bags, in dust form.

Fungicide		Insecticide
Copper	7%[a]	----
do		DDT 5%[a], BHC 3%
do		Toxaphene 10%, BHC 3%
Sulphur	90%	----
do		DDT 5%, BHC 3%
do		Toxaphene 10%, BHC 3%
Ferbam	7.6%	----
do		DDT 5%, BHC 3%
do		Toxaphene 10%, BHC 3%
Zineb	6.5%	----
do		DDT 5%, BHC 3%
do		Toxaphene 10%, BHC 3%
Orthocide 406	1.0%	----
do		DDT 5%, BHC 3%
do		Toxaphene 10%, BHC 3%

[a] Concentration of active ingredient.

Table 2. The fungicides and insecticides, and the concentration of active ingredient in each, that were applied to the sorghum heads as a spray.

Fungicide		Insecticide
Copper	.36%[a]	----
do		Aldrin .5%[a]
do		Toxaphene 2%, Lindane .5%
do		DDT 1%, Lindane .5%
do		Dieldrin .5%
Sulphur	.63%	----
do		Aldrin .5%
do		Toxaphene 2%, Lindane .5%
do		DDT 1%, Lindane .5%
do		Dieldrin .5%
Ferbam	.16%	----
do		Aldrin .5%
do		Toxaphene 2%, Lindane .5%
do		DDT 1%, Lindane .5%
do		Dieldrin .5%
Zineb	.16%	----
do		Aldrin .5%
do		Toxaphene 2%, Lindane .5%
do		DDT 1%, Lindane .5%
do		Dieldrin .5%
Orthocide 406	.13%	----
do		Aldrin .5%
do		Toxaphene 2%, Lindane .5%
do		DDT 1%, Lindane .5%
do		Dieldrin .5%

[a] Concentration of active ingredient.

Table 3. Fungicides, and the concentration of active ingredient in each, used in aqueous suspension to treat the bags prior to placing them on the sorghum heads.

Fungicide	Type	Concentration of active ingredient in percent low	High
Lawn-a-gen	liquid	.03	.06
Spergon	dust	1.33	2.66
Phygon	dust	.33	.65
do	do	1.30	2.61
Panogen	liquid	.98	1.96
Ceresan - M	dust	1.02	2.05
do	do	4.18	8.21
Arasan	dust	.30	.57
Prentox	dust	.30	.57
Tersan	dust	.10	.17

The experiment involving the treatment of bags in fungicide suspensions was made on the Plainsman variety at the Oklahoma A. and M. College Agronomy Farm, Stillwater, Oklahoma. Both of these plots were provided by the Agronomy Department, Oklahoma A. and M. College.

In all of the experiments a randomized block design, or a modification of it, was used. Five plants were used for each replication of the spray and soaked bag treatments and ten plants for each of the dust treatments. The readings on these plants were averaged to give any particular reading for a replication. In general, three replications of each treatment were used.

The methods of recording data were as follows:

(A) Mold. An estimate of the mycelial coverage was rated as; (1) clean, (2) trace, (3) spotty (25 to 40 percent), (4) medium (40 to 75 percent), (5) heavy (100 percent).

(B) Weight. The heads were removed from the plants with approximately one inch of the peduncle. They were weighed individually on a Melvoy Triple Beam Trip Scale to the nearest gram.

(C) Sterility. An estimate was made of the percent of florets on the head that failed to produce seed.

(D) Aphid and worm damage. Estimates of the damage caused by aphids and earworms were made. The ratings used were; (0) none, (1) very slight, (2) slight, (3) moderate, (4) heavy, (5) very heavy.

RESULTS

Sorghum heads were examined during all stages of growth for any indications of fungus development. Glumes, ovaries, dehisced anthers, and seeds were surfaced sterilized with 1:1000 bichloride of mercury solution and placed in petri dishes containing potato-dextrose agar. After a period of 7 days there was sufficient mycelial growth to transfer individual colonies to fresh plates. Over 50 isolates were grown in pure culture on potato-dextrose agar slants. Species of the following genera were identified from these isolates: Fusarium, Helminthosporium, Rhizopus, Alternaria, Pencillium, and Aspergillus. No inoculation studies were made since it was quite evident from the isolations that no one organism predominated. Most of these fungi could be isolated with equal facility from any of the above named plant parts, even following surface sterilization. The moldy condition of sorghum heads seemed to be due to the growth, under extraordinarily favorable conditions provided by the bags, of a number of common air-borne fungi whose spores had become lodged on the head prior to bagging.

So far as could be determined by examination and isolation these fungi first started their development on the anthers as they emerged from the floret. Within a few days, however, cultures of fungi could be obtained from, and external mycelium was found on, all of the other parts of the panicle.

Several experiments were designed to test a number of fungicides for their ability to inhibit or control spore germination and growth of these fungi. In the first experiment the materials listed in table 1 were applied as dusts, either directly to the head, or into the bags before they were placed on the heads. The dusts were applied August 1, 1950.

Preliminary examination of several of the check plants was made after a period of 7 days. At this time, mold growth had started on many of the heads. The bags remained on the heads without further treatment until harvest time, November 1, 1950, when all of the plants were examined, and the data for mold growth, sterility, weight, and insect damage were recorded. These data were analyzed statistically by an analysis of variance. A minium level of significance (M.L.S.) was calculated whenever the "F" value of the analysis of variance indicated a significant difference at odds of 19:1 or greater.

Considering first that portion of the experiment devoted to the use of fungicides alone, analysis of the data indicated that there were no significant differences in mold growth, sterility, or head weight. It was apparent, however, that 90 percent sulphur gave excellent control of the corn leaf aphid (Table 4).

In the remainder of the experiment various fungicide-insecticide combinations were compared. The average relative ratings for mold growth control are compiled in table 5. An analysis of these ratings indicated differences exceeding odds of 99:1. Subsequent breakdown of the analysis (Table 6) showed that a combination of 90 percent dusting sulphur with 5 percent DDT and 3 percent benzene hexachloride, and a combination of 90 percent dusting sulphur with 10 percent toxaphene and 3 percent benzene hexachloride gave better mold control than any of the other treatments.

The heads that were dusted with various fungicide-insecticide combinations showed evidence of some sterility. Estimations of the percent of sterility found are given in table 7. Statistical analysis of these data did not indicate any significant differences among treatments; however, there seemed to be a tendency for combinations involving ferbam to cause more sterility than any of the other fungicides. Similarly more sterility was found with combinations involving DDT than with toxaphene.

Table 4. The relative control of the corn leaf aphid by various fungicides applied to sorghum heads as dusts.

Treatments	Concentration[a] in percent	Corn Leaf Aphid[b] Damage Rating
Copper	7	2.6
Sulphur (dusting)	90	.3
Ferbam	7.6	1.9
Zineb	6.5	2.8
Orthocide 406	1.0	2.2
Control	-	1.2
M.L.S. (19:1)		1.1
(99:1)		1.5

[a] Active ingredient.

[b] Each figure represents the mean of 3 replications of 10 plants. Figures of greater magnitude indicate a greater degree of damage with a minimum of 0.0 and a maximum of 5.0.

Table 5. The relative control of sorghum head mold by various fungicide-insecticide combinations applied as mixed dusts.

Treatment Number	Materials and Concentrations of Active Ingredient in Percent	Average Mold[a] Control Rating
1	Copper 7%, DDT 5%, BHC 3%	2.8
2	do Toxaphene 10%, BHC 3%	2.5
3	Sulphur 90%, DDT 5%, BHC 3%	2.2
4	do Toxaphene 10%, BHC 3%	1.7
5	Ferbam 7.6%, DDT 5%, BHC 3%	2.6
6	do Toxaphene 10%, BHC 3%	2.7
7	Zineb 6.5%, DDT 5%, BHC 3%	3.0
8	do Toxaphene 10%, BHC 3%	2.4
9	Orthocide 406, 1.0%, DDT 5%, BHC 3%	2.4
10	do Toxaphene 10%, BHC 3%	2.4
11	Control	2.9

[a] Each figure represents the mean of 3 replications of 10 plants. Figures of greater magnitude indicate greater degree of infection with a minimum of 1.0 and a maximum of 5.0

Table 6. The analysis of the data contained in table 5, showing the method used to identify the significant treatments.

Variation Due To	Degrees of Freedom	Sum of Squares	Mean Square	"F" Value
Total	29	516		
Replications	2	9	4.5	
Treatments	9	325	36.1	3.6**
Error	18	182	10.	
Treatments	9	325		
Fungicides	4	252	63	6.3**
Insecticides	1	34	34	3.4
Fungicides X Insecticides	4	39	9.75	
Total	4	252		
Treatments numbers 3 and 4 (Table 5) vs. others	1	221	221	22.1**
Other	3	31	10	1.0

** P<0.01

Table 7. The amount of sterility observed on sorghum heads following dust application of various fungicide-insecticide combinations.

Materials and Concentrations of Active Ingredient in Percent	Percent Sterility[a] Materials Applied Directly To The Head	Materials Applied To The Bags
Copper 7%, DDT 5%, BHC 3%	31.0	0.0
do Toxaphene 10%, BHC 3%	27.0	14.0
Sulphur 50%, DDT 5%, BHC 3%	19.7	0.0
do 68%, Toxaphene 10%, BHC 3%	28.8	0.0
Ferbam 7.6%, DDT 5%, BHC 3%	23.0	41.7
do Toxaphene 10%, BHC 3%	11.3	12.3
Zineb 6.5%, DDT 5%, BHC 3%	1.3	18.7
do Toxaphene 10%, BHC 3%	3.7	0.0
Orthocide 406 1.0%, DDT 5%, BHC 3%	2.0	6.0
do Toxaphene 10%, BHC 3%	0.0	7.0
Control	0.0	0.0

[a] Each figure is an average of 3 replications of 10 plants each.

There also seemed to be more sterility evident when the materials were dusted directly on the heads than when they were placed in the bags.

The data for insect damage were not analyzed since it was obvious that all of the insecticides gave excellent control regardless of the fungicide used in the combination. These data are given in table 8. There were no differences in the control of insect damage or mold growth exhibited by the different methods of application. Material applied as dusts into the bags before placing the bags on the heads gave equally as good control as when the materials were dusted directly on the heads.

A second experiment was made August 25, 1950 in which fungicides and fungicide-insecticide combinations were applied directly to the heads as wet sprays. The materials and concentrations listed in table 2 were used in this experiment. The bags remained on the sorghum heads from the time of treatment until November 3, when all of the plants were harvested and the usual records were obtained. The data were analyzed in a manner similar to that of the dusting experiment. There were no significant differences among the sprays containing fungicides alone either for the control of mold growth and insect damage or for their effects on sterility and head weight. Differences between the fungicide-insecticide combinations for average head weight were found which were significant at odds of over 99:1. These data are presented in table 9. Further analysis of the data (Table 10) indicated that the insecticides were responsible for the differences observed in head weight, regardless of the fungicide used in the combination. Combinations involving 0.5 percent Aldrin and those involving 0.5 percent Dieldrin contributed to increased head weight, while those involving 1 percent DDT plus 0.5 percent Lindane reduced head weight below that of the checks. It would appear that the increased head weight might

Table 8. The control of the corn leaf aphid and corn earworm on sorghum heads following dust application of various fungicide-insecticide combinations.

Materials and Concentrations of Active Ingredient in Percent	Aphid[a] Damage Ratings	Earworm[a] Damage Ratings
Copper 7%, DDT 5%, BHC 3%	0.0	0.0
do Toxaphene 10%, BHC 3%	0.0	0.0
Sulphur 50%, DDT 5%, BHC 3%	0.0	0.0
do 68%, Toxaphene 10%, BHC 3%	.03	0.0
Ferbam 7.6%, DDT 5%, BHC 3%	.07	0.0
do Toxaphene 10%, BHC 3%	0.0	0.0
Zineb 6.5%, DDT 5%, BHC 3%	0.0	0.0
do Toxaphene 10%, BHC 3%	0.1	.03
Orthocide 406 1.0%, DDT 5%, BHC 3%	.13	0.0
do Toxaphene 10%, BHC 3%	.03	0.0
Control	1.0	2.3

[a] Each figure represents the average of 3 replications of 10 plants. Figures of greater magnitude indicate greater degree of damage with a minimum of 0.0 and a maximum of 5.0.

Table 9. The effect of various fungicide-insecticide combinations applied as wet sprays on the weight of sorghum heads.

Materials and Concentrations of Active Ingredient in Percent		Average Weight of[a] heads in grams
Copper .36%,	Aldrin .5%	112.
do	Toxaphene 2%, Lindane .5%	65.2
do	DDT 1%, Lindane .5%	36.4
do	Dieldrin .5%	102.
Sulphur .63%,	Aldrin .5%	99.6
do	Toxaphene 2%, Lindane .5%	77.8
do	DDT 1%, Lindane .5%	69.8
do	Dieldrin .5%	116.2
Ferbam .16%,	Aldrin .5%	99.6
do	Toxaphene 2%, Lindane .5%	53.6
do	DDT 1%, Lindane .5%	39.2
do	Dieldrin .5%	107.0
Zineb .16%,	Aldrin .5%	97.8
do	Toxaphene 2%, Lindane .5%	65.0
do	DDT 1%, Lindane .5%	61.2
do	Dieldrin .5%	98.6
Orthocide 406 .13%,	Aldrin .5%	111.6
do	Toxaphene 2%, Lindane .5%	74.8
do	DDT 1%, Lindane .5%	44.0
do	Dieldrin .5%	126.8
Control		71.0

[a] Each figure represents the mean of 3 replications of 5 plants.

Table 10. The analysis of the data contained in table 9, showing the relative effects of the fungicides and the insecticides on the differences noted in average weight of sorghum heads.

Variation Due To	Degrees of Freedom	Sum of Squares	Mean Square	"F" Value
Total	59	6602.2		
Replications	2	343.1	171.6	
Treatments	19	4830.0	254.2	6.87**
Error	38	1429.1	37.6	
Treatments	19	4830.0		
Fungicides	4	253.3	63.3	1.6
Insecticides	3	4182.9	1394.3	37.0**
Fungicides X Insecticides	11	393.8	35.8	

**$P < 0.01$

be attributed to the control of insect damage by these materials, and the decrease in head weight might be caused by sterility. However, no differences between these combinations were noted, either for insect control or sterility; all of the materials gave excellent control of insects and exhibited negligible sterility.

The bags used to cover the sorghum heads were dipped in aqueous suspensions of various fungicides in a third experiment made September 9, 1950. The materials used in this experiment were selected on the basis of their supposed volatility. Since no precedent for the use of any of these materials in this manner had been established, two concentrations were arbitrarily selected; the high concentration being just double the low concentration in all cases except with Phygon and Ceresan M which were used at four concentrations.

The bags were dipped in aqueous suspensions of these materials, dried, and applied to the sorghum heads in the usual manner. The plants were harvested and the data recorded November 18, 1950.

The data on the control of head mold, corn leaf aphid, and corn earworm are given in table 11. No differences in head weight or sterility could be detected. Ceresan M and Panogen gave the best control of head mold. Differences significantly better than the untreated plots at odds of over 99:1 were indicated for two of the four concentrations of Ceresan M (1.02 and 4.18 percent ethyl mercury p-toluene sulfonanilide) and for both concentrations of Panogen (0.98 and 1.96 percent methyl mercury dicyan diamide). The same two concentrations of Ceresan M together with Phygon (0.33 percent 2,3-dichloro - 1,4-naphthoquinone) and Prentox (0.30 percent 2,4,5 trichlorophenyl acetate) gave the best control of the corn leaf aphid; differences significantly better than the untreated plots at

Table 11. The relative control of sorghum head mold, corn earworm, and corn leaf aphid by various fungicides applied to the bags as a liquid suspension prior to bagging the heads.

	Low Concentration				High Concentration			
Treatment	Concentration[a] in Percent	Mold Av. Rating	Leaf Aphid Av. Rating	Earworm[b] Av. Rating	Concentration[a] in Percent	Mold Av. Rating	Leaf Aphid[b] Av. Rating	Earworm Av. Rating
Lawn-a-gen	.03	3.3	3.2	1.2	.06	3.0	2.6	1.5
Spergon	1.33	3.4	2.9	1.4	2.66	3.0	2.7	.7
Phygon	.33	3.0	1.9	1.7	.65	2.5	2.3	1.1
do	1.30	2.9	2.4	1.9	2.61	2.6	1.0	.3
Panogen	.98	2.5	2.4	1.1	1.96	1.8	1.5	.8
Ceresan-M	1.02	2.3	1.0	1.4	2.05	2.4	1.3	1.4
do	4.18	2.0	1.3	.05	8.21	2.5	2.1	.08
Arasan	.30	2.9	2.3	1.3	.57	2.9	2.3	1.0
Prentox	.30	3.1	1.9	1.3	.57	3.0	2.4	.3
Tersan	.10	3.3	2.3	.03	.17	2.9	2.4	.5
Control	-	3.5	3.3	1.9	-	3.0	2.5	2.0
M.L.S. (19:1)		.6	1.3			.6		.7
(99:1)		.7	1.7			.8		.9

[a] Active ingredient

[b] "F" value for the analysis of variance indicated no significance.

odds of 99:1 being indicated only for the two concentrations of Ceresan M.

A germination test was made of seed from heads whose treatments had given the best control of mold, and of seed from severely molded heads. The germinator used was maintained at a temperature of 70 degrees F. The seeds were placed on trays in randomized blocks with three replications. In order to maintain like conditions for each block, the trays were rotated every other day. After a period of 7 days the trays were checked and scored. Scores of; (1) no germination, (2) weak, (3) moderate, and (4) vigorous, were based on the growth of the coleoptile. Statistical analysis of the data showed that there were no significant differences in germination between the seed from the heads where mold had been satisfactorily controlled and the seed from severely molded heads.

The test was not truly indicative of the loss due to molded heads, however. In the process of threshing molded heads, most of the seed encrusted with mold and insect frass is lost or discarded with the other panicle parts, so that, in general, only the sound, relatively clean seed remains. The germination test did show, however, that the seed obtained from molded heads did not contain any higher concentration of internally born parasitic organisms than did seed from healthy, clean heads.

DISCUSSION

Extensive observations, both macroscopic and microscopic, together with hundreds of isolations have indicated rather clearly that head mold of sorghum may be brought about by any one or several of a number of saprophytic, or weakly parasitic fungi. The spores of these fungi are commonly carried in the air, some of them becoming lodged on the sorghum head after it emerges from the boot. When a paper bag is applied to the sorghum head to exclude foreign pollen the relative humidity inside the bag becomes quite high providing excellent conditions for the germination and growth of whatever fungi are present. The dehisced anthers provide suitable food material initially, followed later by a limited parasitism of other structures in the panicles.

It seemed that control of this condition could best be attained through the use of fungicides, and to test this hypothesis a number of fungicides and fungicide-insecticide combinations were used as dusts, sprays, and as a pre-soak for the bags.

When used as dusts none of the fungicides alone gave adequate control of head mold. However, by combining these fungicides with certain insecticides it was possible to obtain at least limited control of head mold. A combination of 90 percent dusting sulphur with 5 percent DDT and 3 percent benzene hexachloride, and a combination of 90 percent dusting sulphur with 10 percent toxaphene and 3 percent benzene hexachloride gave better mold control than any of the other combinations. However, the control of mold by these combinations can not be attributed solely to the control of insects since insect damage was adequately controlled with all of the fungicide-insecticide combinations.

Applying the dust materials to the inside of the bags themselves gave equally as good control of both mold and insects as applying the dusts directly to the heads. This method has two advantages. The operation can be done in the laboratory before taking the bags to the field, and while analysis did not indicate significant differences, there seemed to be considerably more sterility when the materials were dusted directly on the heads. This was particularly true with combinations involving either ferbam or DDT.

Wet spray applications of the fungicides alone and in combination with various insecticides gave no control of head mold, even though those plants treated with fungicide-insecticide combinations were relatively free of insects. The inability of wet sprays to control mold may be attributed to the fact that the sorghum heads were extremely difficult to wet. The amount of run-off after spraying was excessive with all of these materials. The need for some type of spreader-sticker adjuvant is indicated if wet sprays are to be applied to sorghum heads. Clearly, the total amount of active ingredient actually remaining on the heads was much lower when the materials were applied as a wet spray compared to applications of dust.

Probably the most significant result found in these studies was the control of head mold obtained by presoaking the bags before they are placed on the sorghum heads. This method would be the most advantageous for the plant breeder because it does not involve an extra field operation. Certain concentrations of Ceresan M and Panogen gave good control of head mold when applied to the bags as an aqueous suspension. Further study would be required to establish the best concentration to use, and perhaps other materials of a volatile or semi-volatile nature could be found which would give even better control. The difficulties encountered in treating the bags with suspensions might be eliminated if suitable solvents could be found. The results so far obtained certainly indicate that additional tests along this line would be advantageous.

SUMMARY

1. Observations and isolations indicated that sorghum head mold is caused by any one or more of several saprophytic or semi-parasitic fungi which develop after bags are applied to the heads to control pollination.

2. Certain fungicides applied to the heads and into the bags as dusts failed to give adequate head mold control.

3. Combinations of fungicides and insecticides applied as mixed dusts to the heads and into the bags gave excellent insect control in all cases; and certain combinations, notably 90 percent sulphur with 5 percent DDT and 3 percent benzene hexachloride and sulphur with 10 percent toxaphene and 3 percent benzene hexachloride gave good control of head mold.

4. Increased sterility was noted when certain materials were applied directly to the head as dusts, particularly combinations involving ferbam, and combinations involving DDT.

5. Certain fungicides applied to the sorghum heads as wet sprays failed to give control of head mold.

6. Combinations of fungicides and insecticides applied to the sorghum heads as wet sprays gave adequate control of insects, but failed to control head mold. The failure of wet spray fungicide and insecticide combinations to control head mold has been attributed to excessive run-off leaving only a very light deposit of active material.

7. Certain volatile or partially volatile fungicides were applied to the bags by soaking the bags in a water suspension of the fungicide before it was used to cover the sorghum head. Good control of head mold

was obtained with two concentrations of Ceresan M and with two concentrations of Panogen.

THESIS TITLE: Preliminary studies of Sorghum head mold and its control.

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