# THE USE OF, AND EQUIPMENT FOR APPLYING MOLD INHIBITORS IN BALED HAY

Thesis for the Degree of M. S.

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Cecil Howard Eggleton, Jr.

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This is to certify that the

thesis entitled

"The Use of, and Equipment for Applying Mold Inhibitors in Baled Hay"

presented by

Cecil Howard Eggleton, Jr.

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# THE USE OF, AND EQUIPMENT FOR APPLYING MOLD INHIBITORS IN BALED HAY

By

Cecil Howard Eggleton, Jr.

AN ABSTRACT

Submitted to the School of Graduate Studies of Michigan State College of Agriculture and Applied Science in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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THESIS

A simple, efficient, and economical method of preventing mold and bacterial action in stored hay was the subject of this investigation. Hay baled at a moisture content of 30 percent or higher, to eliminate mechanical damage, must be protected from the destructive action of mold and bacteria.

Removing the excess moisture from the hay with forced air has been employed to cure high moisture content hay. With baled hay, now the most widely used method of storage preparation, forced air systems have not been simple or particularly efficient.

If a chemical could be found, which, when coupled with a simple method of application, would prevent mold growth from occuring in stored baled hay, a great service will have been done for agriculture.

The experimentation reported in this thesis was carried out during the summer of 1952. The first cutting tests employed one method of application and three chemicals. Dowicide A, Dowicide B, and D.H.A.S., in water solutions, were sprayed on the standing hay immediately before mowing. The application rate was approximately two pounds of chemical to one ton of 30 percent moisture content hay.

Test bales, of known moisture content and weight, were graded according to official U.S. hay grades after curing to

evaluate the results of treatment. Dowicide A and D.H.A.S. were ineffective in controlling mold. The Dowicide B treated hay was in better condition than the Control or other treated lots, although control of must was not attained.

Coverage of heavy first cutting alfalfa was difficult with the spray method. Partial insolubility of Dowicide A and Dowicide B was an additional source of difficulty.

For the second cutting tests, four methods of application were devised, employing Dowicide 2S in dust and mineral oil solution, and propionic acid as the mold inhibiting compounds.

The Dowicide 2S dust was applied directly into the bale chamber by a crop preservative dust dispenser and a greenhouse duster mounted on the baler. Dowicide 2S dissolved in mineral oil was applied to the hay at two points on the baler, directly into the bale chamber and on the feeding apron. One spray nozzle was employed at the bale chamber and three at the feeding apron. Propionic acid was applied with the single nozzle bale chamber spray unit.

For the second cutting tests, a new method of sampling each bale for moisture content was devised. Official U.S. grades were placed on all bales after curing for evaluation of the chemical treatment. Few of the treated bales contained mold upon inspection. Of the four methods of chemical application, the mounted greenhouse duster produced the most

adequate coverage. The objectionable cloud of chemical surrounding the unit, however, renders this method impractical. With additional nozzles, the bale chamber spray is recommended as the most satisfactory method of application.

Dowicide 2S was found to be effective in controlling mold growth. An application of 7.4 pounds of Dowicide 2S per ton of hay with the greenhouse duster produced the most satisfactorily cured run of test bales. Complete control of must was not attained in any of the treated hay. Application rates higher than seven pounds of Dowicide 2S per ton of hay will be required to produce complete control of must and mold.

Propionic acid was found to be ineffective in controlling mold.

Approved D. E. Weimer

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Grades were placed on each test bale by the experienced judgement of Professor H. R. Pettigrove, Farm Crops Department, to whom grateful thanks are given for this invaluable contribution.

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# INTRODUCTION

## The Mold Problem

To retain the greatest possible feeding value when harvesting hay, it is important to reduce field exposure to a minimum and to complete all handling operations while the hay contains at least 30 percent moisture.* (4,10,15,30) Harvesting in this manner insures retention of the green color and sweet, leafy portion of the hay, and therefore results in a more nutritious and palatable roughage feed for livestock.

Completing the harvest at 30 percent moisture content may be easily accomplished. Upon storage of the hay, however, mold and bacterial action will readily occur. If the destructive action of mold and bacteria is allowed to continue unchecked, the hay can become worthless as a feed. The heating caused by mold and bacteria can begin the temperature rise which results in spontaneous combustion within the hay mass.

The problem centers in preventing mold and bacterial losses in high moisture content hay. To gain acceptance, the solution to the problem must be both efficient and economical.

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*Moisture contents in this thesis are percent wet basis.

## Scope of the Investigation

This investigation has as its subject chemical mold inhibiting compounds and their use with baled hay. Baling of hay has become popular to such a degree that in 1948, 47 percent of the hay produced in the United States was baled. (18) Preliminary estimates for the year 1952 indicate more than 65 percent was baled. Field pick up balers, some entirely automatic, are the primary reason for this popularity.

Storage curing of baled hay presents some unique problems, and mold inhibiting compounds have a definite place in their solution.

## Factors Influencing Mold Growth in Hay

Snow (25) listed the following factors as paramount in the occurrence of mold in stored hay.

The relative humidity of storage. This is an indirect method of stating moisture content of the hay, especially in baled hay. Bales are actually small storage chambers and may have a high relative humidity within them due to the moisture content of the hay. Dawson (6), uses moisture potential as the factor but makes the following statement:

> When hay is to be barn dried (i.e. moisture content is over 25 percent) it makes little, if any difference whether moisture potential or moisture content is used for characterizing the moisture status of hay for mold growth. This is true because moisture potential under these conditions is always initially high enough for rapid mold growth.

Density of bale is an additional factor to be considered with moisture content, for if the bale is of such density that

moisture may not evaporate readily, mold growth may occur with moisture contents below 20 percent. A typical farm hay bale weighing 50 to 60 pounds, however, will not support mold growth after the moisture content has been reduced to 20 percent.

Length of storage period. Mold forms rapidly in baled hay when the moisture content is over 20 percent. Jennings (12) found that to cure hay with no mold occuring, the moisture content must be reduced to 20 percent within 4 days, regardless of the initial moisture content. Other investigators (8,27) have mentioned the undesirability of protracted drying time.

The balance and type of nutrients available. The most readily available nutrients are the first to be destroyed by mold (25). In Table I are data for comparison of feeding value of normal, brown and black hay, as presented by Hodgson (10).

The temperature of storage. Summer storage temperatures and heat produced by initial respiration combine to provide the optimum temperature for mold growth. Millar (20) suggested refrigeration as a possible control of mold in hay. Pasteurization might also be employed if the material could be protected from further exposure after treatment. These methods suggest an investment which could hardly be justified.

TABLE I

RELATIVE NUTRITIVE VALUE AND PALATABILITY OF NORMAL HAY AND OF HAY THAT HAS HEATED IN THE STACK

| | Normal Hay | Brown Hay | Black Hay |
|---|---|---|---|
| Calculated digestible nutrients: | | | |
| Protein | 14.4% | 3.4% | 0.6% |
| Total | 55.8% | 37.7% | 23.4% |
| Palatibility: | | | |
| Pounds eaten for 1000 pounds weight | 20 lb. | 15 lb. | 10 lb. |

The type of mold species on the hay. Lewis (16) has isolated the types of molds most commonly found on baled hay in the Lansing, Michigan area. Table II shows the results of these isolations. Lewis states that these same molds are the most common found in the soil of the area. This is to be expected considering the relationship between soil and crop.

Methods of Curing High Moisture Content Baled Hay

Mow finishing with forced air. (8,10,12,13) By removing the excess moisture rapidly, it is possible to produce good quality hay. A number of limiting factors, however, are encountered when attempting to dry baled hay. Initial investment is substantial in high output fans, special ducts and mow floors. A great deal of labor is involved in

placing the bales over the duct system to minimize loss of air through cracks and crevices between bales. The bales must be low in density so the air will pass through them, which is the requirement for proper drying. Often, the moisture content of the center portion of the bales is not reduced rapidly enough (12) and mold losses do occur. (11)

TABLE II

THE TEN MOST COMMON FUNGI ISOLATIONS FROM HAY IN LANSING, MICHIGAN AREA(16)

| Organism | No. Isolations from 30-40% Moisture Hay | No. Isolations from 10-20% Moisture Hay |
|---|---|---|
| Mucor sp. | 18 | 11 |
| Aspergillus niger | 11 | 10 |
| Aspergillus fumigatus | 9 | 4 |
| Penicillium expansum | 11 | 2 |
| Rhizopus sp. | 6 | 9 |
| Alternia sp. | 5 | 8 |
| Fusarium sp. | 9 | 1 |
| Aspergillus glaucus | 3 | 6 |
| Aspergillus repens | 4 | 2 |
| Trichloderma sp. | 3 | 0 |

Eighteen samples of 30-40% moisture hay used for isolations.

Twelve samples of 10-20% moisture hay used for isolations.

Crop preservatives including salt. Recently a number of commercial crop preservatives have appeared on the market. Briefly, the theory of their operation is: the sodium bicarbonate and calcium bicarbonate, of which they are composed, decompose upon contact with moisture in the hay and produce carbon dioxide within the hay mass. The carbon dioxide displaces the oxygen and prevents mold and bacterial action. All scientific investigation with these products has denounced them as valueless. (13,22)

Common salt has been used as a mold inhibitor for a number of years and has received both favorable and unfavorable comment. (17,22) There is an indication of slight mold inhibition but the flavoring effect is considered to be its most beneficial contribution.

Chemical mold inhibitors. Lewis (16) conducted laboratory experiments with a number of the fatty acids on rewetted hay. Propionic acid, butyric acid and valeric acid were effective in controlling mold. Limited field tests, in which the acids were sprayed in front of the mower cutter bar, indicated that the volatile nature of the acids was the cause of ineffective results. Some of these acids have an unpleasant odor, e.g. the objectionable odor in rancid butter is caused by butyric acid and would therefore be limited in use.

In 1950, Dawson, Musgrave and Danielson (7) conducted tests with a number of fungicidal compounds on small samples of chopped hay. Four-gram samples of air dried hay were first

treated with fungicide, then water suspensions of fungus were applied to bring the hay to equilibrium moisture content at 85 percent relative humidity. Relative humidity of storage was maintained at 85 percent during the incubation period of from four to eight weeks. The samples were then dried and dry matter loss calculated as an indication of mold growth. Three compounds; Dowicide 2,[1] Dowicide 2S,[2] and mycotox No. 1,[3] at rates of six to eight pounds per ton of hay, were reported to have completely controlled mold losses.

Three additional compounds; mycotox No. 12,[4] mycotox No. 20,[5] and Dowicide 1 [6] were reported to warrant further study.

Anderson, et. al. (1) reported beef cattle feeding trials with derivatives of 2,4,5-trichlorophenol. The compounds were fed at a rate up to nine times that which would result if the cattle were fed cottonseed meal treated to prevent mold. When the animals were slaughtered an inspection showed no adverse effects in those organs inspected, the meat or blood composition.

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[1]Dowicide 2. . . . . 2,4,5-trichlorophenol
[2]Dowicide 2S . . . . 2,4,6-trichlorophenol
[3]mycotox No. 1 . . . 2,4,5-trichlorophenol acetate
[4]mycotox No. 12. . . tetrachlorophenyl acetate
[5]mycotox No. 20. . . tetrachlorophenyl propionate
[6]Dowicide 1. . . . . orthophenylphenol

In 1951 Richards (24), at Michigan State College, conducted laboratory and field tests on baled hay with Dowicide A,[1] Dowicide B,[2] Dowicide 2S,[3] and D.H.A.S.[4] Water solutions of a known concentration were sprayed at a known application rate on the standing hay immediately before mowing.

Dowicide A and Dowicide B were concluded to be effective in controlling mold in baled hay at a moisture content of 30 percent, with Dowicide B showing the most promising results. Dowicide 2S was found to be difficult to dissolve in a water solution and, even when a caustic was added, only partial solubility resulted.

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[1]Dowicide A . . sodium o-phenylphenate
[2]Dowicide B . . sodium trichlorophenate
[3]Dowicide 2S. . 2,4,6-trichlorophenol
[4]D.H.A.S. . . . Di-hydro acetic acid sodium salt

## OBJECTIVES OF THE INVESTIGATION

The principal objective of the investigation was to obtain mold and must free baled hay, using bales containing 30 percent moisture content and weighing 55 to 60 pounds. Mold and must free curing was sought with the aid of chemical mold inhibitors, presenting the following secondary objectives:

1. To conduct further tests with the application of chemical on the standing hay, similar to the method used by Richards, in heavy first cutting alfalfa.

2. To conduct tests with various methods of application at points after the hay has been cut.

3. To determine effectiveness of additional chemicals and varying rates of application.

# EXPERIMENTATION

## First Cutting Tests

Apparatus and equipment.

1. Two 2 plow tractors.

2. Portable spray unit, equipped with a ten foot, five nozzle boom, mounted on tractor platform. (Fig. 1)

3. Seven foot mounted mower. (Fig. 2)

4. Left hand side delivery rake.

5. Field pick up automatic twine tie baler. Bale size 14"x18"x38". (Fig. 3)

6. Five 4 wheel wagons and power equipment to haul hay to storage.

7. Paper sacks and scales for moisture content determination samples.

8. Small 2 wheel trailer with enclosed box to house miscellaneous equipment and samples during field operation.

9. Hay curing laboratory. An 82'x20' structure, containing 6-12'x20' storage compartments and a 10'x20' instrument room. Three compartments were enclosed, three had open sides and wire floors for natural draft ventilation.

10. Brown 12 point recording potentiometer within instrument room to read temperatures of the 3 sets of copper-constantan thermocouples installed in each storage compartment.

11. Electric oven for drying moisture content determination samples.

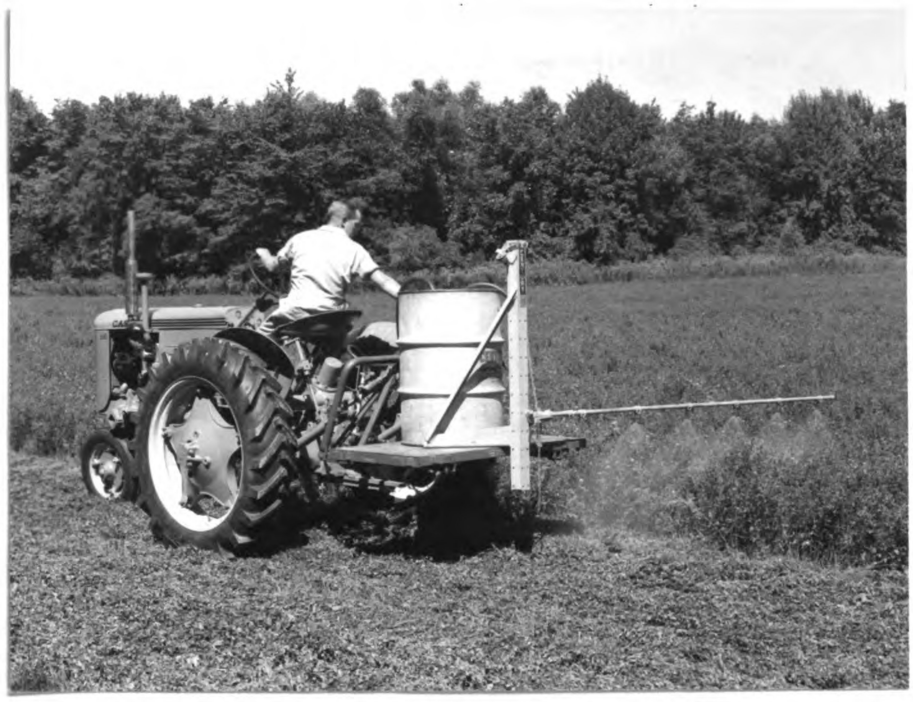

Fig. 1. Five nozzle spray unit

Fig. 2. Applying mold inhibitor ahead of mower

Fig. 3. Automatic twine tie baler in action

General procedure. The first cutting tests were conducted in a manner similar to the procedure that Richards had used in 1951. Water solutions of the chemicals were used in the concentration of five pounds of chemical to fifty gallons of water. The solution was applied immediately in front of the mower at the rate of 50 gallons to the acre. (Fig. 2)

The hay was allowed to dry in the swath until the moisture content was reduced to approximately 50 percent, when it was raked into windrows with the left hand side delivery rake. Raking proceeded at a rate determined by the drying rate of the hay and in the same direction as the mower.

Drying continued in the windrow and when the desired moisture content for baling, 30 percent, was approached, baling began. (Fig. 3)

As baling proceeded, a sample of hay was collected from the center portion of the windrow immediately in front of the pick-up baler. When this portion of the windrow was baled a tag was placed on the bale to designate it a test bale. The collected sample was placed in a paper sack, marked with the respective test bale number, weighed and later taken to the laboratory to be dried in an electric oven. From 4 to 8 samples per ton were taken as each test lot was baled. The moisture content of the sample represented

the moisture content of the respective test bale, and the average moisture content of all the samples was taken as the moisture content of the entire test hay.

All bales were stored in the open sided compartments of the hay laboratory. These compartments are open on the north and south sides and have wire mesh floors. The bales were stacked tightly together, on edge, with each succeeding layer perpendicular to the preceeding layer. All test bales were weighed before being placed in storage and their locations in storage were recorded to facilitate removal for inspection. Copper-constantan thermocouples were placed in the center of representative bales within each test lot and the temperature of the bales during the curing period was recorded.

The tests conducted during the first cutting were designated according to the chemical applied as follows:

Set 1, Dowicide B

Set 2, Dowicide B

Dowicide A

D.H.A.S.

Control

Set 1, Dowicide B. Five pounds of Dowicide B, plus one half pint of Methocel Paste was added to 50 gallons of water in the sprayer tank. Methocel Paste is a detergent used to decrease the surface tension of the water and increase the coverage. The chemical was stirred into solution

by hand and by circulating through the pump. The resulting product contained many small particles, which, when pressed together, produced spongy, sticky masses. These particles continually clogged the pump intake screen, and because of this difficulty, only one half acre was treated and cut for the test.

Spraying and mowing took place during early afternoon of July 1, 1952, and the hay was raked into windrows late the following morning. An impending thundershower forced the baling for the afternoon of July 2, 1952, when the moisture content of the hay was 40 percent. The bales were then placed in storage as previously described.

Set 2, Dowicide A, Dowicide B, D.H.A.S., Control. On July 4, 1952, another set of tests using Dowicide B, Dowicide A, and D.H.A.S. was begun. The procedure for mixing the chemicals was altered somewhat in an attempt to eliminate the previous screen clogging trouble.

The chemicals were pre-mixed in a twelve quart pail before being placed in the 50 gallon tank. The floating and suspended particles previously encountered were eliminated, but a sticky, slimy mass was deposited on the bottom of the tank by both Dowicide B and Dowicide A. The chemical D.H.A.S. was completely soluble in water, producing a milky-like solution in the tank.

Concentration of solution, 5 pounds of chemical to 50 gallons of water, was maintained during the tests of Set 2. Application rate remained the same, 50 gallons per acre. The detergent, Triton X-100, was used in the concentration of one pint to 50 gallons of chemical solution.

Hay for the three chemical test lots was sprayed and mowed the morning of July 4, 1952. The control lot was also mowed at this time. The Dowicide A and Dowicide B test lots were raked during the afternoon of the day cut and were baled the following morning. The D.H.A.S. and control lots were raked during the morning of July 5, 1952 and baled in the early afternoon.

The moisture content of each test lot, as determined by the average sample moisture content, was:

Dowicide B - 24 percent
Dowicide A - 27 percent
D.H.A.S. - 26 percent
Control - 24 percent

The application rate of five pounds per acre on this stand averaging two and one half tons per acre resulted in an amount of chemical on the hay of two pounds per ton.

Results and discussion. The bales were kept in storage for one month before being removed for inspection and grading. Professor H. R. Pettigrove, Farm Crops De-

partment, Michigan State College, graded each test bale according to official United States Hay Grades.

Hay may be designated U.S. 1, U.S. 2, U.S. 3, or U.S. SAMPLE grade, as determined by the following factors: color, leafiness in legumes, maturity of plants when cut, amount of foreign material, condition (musty or moldy) and texture. (27) These factors are direct indications of the palatability, digestibility, and nutritive value of the hay. Any amount of must or mold present disqualifies the hay for a numbered grade and places it U.S. SAMPLE grade. Thus, any test bales graded U.S. 3 or higher are free of must or mold. For purposes of this investigation, successful curing implies hay graded U.S. 3 or higher.

The complete grade of a bale contains; first, the grade of the bale; second, the type of hay; and third, the reason for each grade.

Tables III, IV, V, VI, and VII indicate the result of the test bale inspection for the four first cutting tests and control lot.

The Dowicide B treated hay of Set 1 was baled at a moisture content of 40 percent, considerably higher than that which was desired to be cured with the aid of mold inhibitors. This high moisture content produced dense bales which was also undesirable. Bales of 30 percent moisture

TABLE III

BALE INSPECTION DATA - SET 1, DOWICIDE B
APPLICATION - 2 LB. DOWICIDE B PER TON

| Bale No. | Moisture Content-% | Weight in-lb. | U.S. Grade |
|---|---|---|---|
| 39 | 34.0 | 63 | SAMPLE<br>Alfalfa-medium grass mix, musty. |
| 172 | - | 47 | 3<br>Alfalfa-heavy grass mix, color, some chemical odor. |
| 161 | 31.8 | 41 | 3<br>Alfalfa-heavy grass mix, color, some chemical odor. |
| 57 | 36.4 | 62 | SAMPLE<br>Alfalfa-musty, moldy. |
| 223 | - | 56 | SAMPLE<br>Alfalfa-musty, moldy. |
| 204 | 41.0 | 71 | SAMPLE<br>Alfalfa-musty, moldy. |
| 10 | 47.6 | 74 | SAMPLE<br>Alfalfa-medium grass mix, very musty, slightly moldy. |
| 246 | 44.2 | 82 | SAMPLE<br>Alfalfa-light grass mix, very musty, very slightly moldy. |
| 114 | 39.4 | 80 | SAMPLE<br>Alfalfa-heavy grass mix, very musty and moldy, especially middle of bale. |
| 21 | 43.6 | 92 | SAMPLE<br>Alfalfa-light grass mix, very very musty and slightly moldy. |
| Ave. | 40.0 | 67 | 2 U.S. 3 grade |
| Range | 31.8-47.6 | 41-92 | 8 U.S. SAMPLE grade |

TABLE IV

BALE INSPECTION DATA - SET 2, DOWICIDE B
APPLICATION - 2 LB. DOWICIDE B PER TON

| Bale No. | Moisture Content-% | Weight in-lb. | U.S. Grade |
|---|---|---|---|
| 201 | - | 59 | SAMPLE<br>Alfalfa-musty. |
| 205 | 20.8 | 46 | 3<br>Alfalfa-heavy grass mix, color, some chemical odor. |
| 43 | 17.1 | 50 | 3<br>Alfalfa-heavy grass mix, color, decided chemical odor. |
| 77 | 22.7 | 43 | 3<br>Alfalfa-heavy grass mix, color, decided chemical odor. |
| 211 | 17.4 | 40 | 3<br>Alfalfa-medium grass mix, color, some chemical odor. |
| 208 | - | 52 | 3<br>Alfalfa-light grass mix, color, some chemical odor. |
| 222 | 19.5 | 60 | SAMPLE<br>Alfalfa-light grass mix, slightly musty. |
| 223 | 26.1 | 49 | SAMPLE<br>Alfalfa-slightly musty one end of bale, slight chemical odor other end. |
| 13 | 26.0 | - | 3<br>Alfalfa-heavy grass mix, color, slight chemical odor. |
| 227 | 17.8 | 49 | 3<br>Alfalfa-medium grass mix, color, very slight chemical odor. |
| 83 | 39.0 | - | 3<br>Alfalfa-heavy grass mix, color, very, very slight chemical odor. |

TABLE IV

(CONTINUED)

| Bale No. | Moisture Content-% | Weight in-lb. | U.S. Grade |
|---|---|---|---|
| 50 | 32.3 | 50 | 3<br>Alfalfa-heavy grass mix, color, slight chemical odor. |
| 99 | 20.1 | 44 | 3<br>Alfalfa-heavy grass mix, color, decided chemical odor. |
| 30 | - | 54 | SAMPLE<br>Alfalfa-medium grass mix, color, very slightly musty. |
| 202 | 36.2 | 55 | 3<br>Alfalfa-medium grass mix, color, slight chemical odor. |
| 210 | 26.1 | 46 | 3<br>Alfalfa-medium grass mix, color. |
| Ave. | 24.4 | 50 | 12 U.S. 3 grade |
| Range | 17.1-39.0 | 40-60 | 4 U.S. Sample grade |

TABLE V

BALE INSPECTION DATA - SET 2, DOWICIDE A
APPLICATION - 2 LB. DOWICIDE A PER TON

| Bale No. | Moisture Content-% | Weight in-lb. | U.S. Grade |
|---|---|---|---|
| 252 | 20.3 | 45 | 3<br>Alfalfa-heavy grass mix, color. |
| 176 | 44.2 | 42 | 3<br>Alfalfa-heavy grass mix, color. |
| 12 | 16.3 | 42 | 3<br>Alfalfa-heavy grass mix, color. |
| 26 | 23.4 | 51 | SAMPLE<br>Alfalfa-very slightly musty. |
| 206 | 22.3 | 45 | 3<br>Alfalfa-heavy grass mix, almost an ensilage odor in part of it and almost musty odor in two flakes, color. |
| 222 | 20.2 | 49 | SAMPLE<br>Alfalfa-medium grass mix, slightly musty. |
| 56 | 30.6 | 45 | SAMPLE<br>Alfalfa-medium grass mix, one end of bale very slightly musty. |
| 205 | 39.2 | 40 | 3<br>Alfalfa-heavy grass mix, color. |
| 211 | 20.9 | - | 3<br>Alfalfa-heavy grass mix, color. |
| Ave. | 26.6 | 45 | 6 U.S. 3 grade |
| Range | 16.3-44.2 | 40-51 | 3 U.S. Sample grade |

TABLE VI

BALE INSPECTION DATA - SET 2, D.H.A.S.
APPLICATION - 2 LB D.H.A.S. PER TON

| Bale No. | Moisture Content-% | Weight in-lb | U.S. Grade |
|---|---|---|---|
| 191 | 24.3 | 46 | 3<br>Alfalfa-heavy grass mix, color. |
| 268 | 20.3 | 54 | SAMPLE<br>Alfalfa-heavy grass mix, musty. |
| 206 | 20.0 | 50 | 3<br>Alfalfa-heavy grass mix, color. |
| 145 | - | 39 | 3<br>Alfalfa-heavy grass mix, color. |
| 146 | 34.6 | 50 | SAMPLE<br>Alfalfa-light grass mix, musty, moldy, moldy area wet. |
| 205 | 30.2 | - | 3<br>Alfalfa-light grass mix, color. |
| Ave. | 25.9 | 48 | 4 U.S. 3 grade |
| Range. | 20.0-34.6 | 39-54 | 2 U.S. Sample grade |

TABLE VII

BALE INSPECTION DATA - SET 2, CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content-% | Weight in-lb. | U.S. Grade |
|---|---|---|---|
| 208 | 31.4 | 61 | SAMPLE<br>Alfalfa-light grass mix, musty. |
| 204 | 26.6 | 40 | 3<br>Alfalfa-heavy grass mix, color. |
| | | | 1 U.S. 3 grade |
| | | | 1 U.S. Sample grade |

content weighing 55 to 60 pounds were sought as desirable for these tests. When this test lot was inspected and graded, ten of the twelve test bales graded U.S. sample, musty and moldy. The two grading U.S. 3 were somewhat over 30 percent moisture content but were of lighter weight than desirable.

Test bales of the Dowicide B test lot in Set 2 graded somewhat better than those in Set 1. Moisture content and density were within the desirable range on these bales. Of the sixteen test bales, twelve graded U.S. 3 and four graded U.S. Sample. (Table IV)

Bales treated with Dowicide A were low in density and within the range of moisture contents desirable for mold inhibitor curing. Six of these bales graded U.S. 3 and three graded U.S. Sample.

Low density and low moisture content characterized the bales treated with D.H.A.S. Four of these bales graded U.S. 3 and two graded U.S. Sample grade.

The limited number of test bales in the control lot makes the comparison to treated hay somewhat questionable. Of the two test bales, one graded U.S. 3 and one graded U.S. Sample. The U.S. 3 bale was of low density and low moisture content.

Moisture content ranges in each test were as follows:

Set 1, Dowicide B. 31.8-47.6 (10 bales)

Set 2, Dowicide B. 17.1-39.0 (16 bales)

Dowicide A. 16.3-44.2 ( 9 bales)

D.H.A.S. 20.0-34.6 ( 6 bales)

Control 26.6-31.4 ( 2 bales)

A slight variation in moisture content may be evident within any hay field but the wide ranges shown here are difficult to justify as field variations.

The Dowicide A and Dowicide B tests in Set 2 were extremes in their wide range of moisture contents.

Inaccurate moisture content determination was believed the answer. The method of choosing a small handful of hay, from the windrow in front of the baler, and to have it represent an entire bale was not adequate. A baler may travel from 15 to 30 feet along the windrow to produce one bale, depending on the stand.

Another illustration of inaccurate moisture content figures was evident when bales No. 202 and 222 of Dowicide B, Set 2 were compared:

Bale No. 202 36% M.C. 55 lb. U.S. 3 grade

Bale No. 222 19.5% M.C. 60 lb. U.S. Sample

Bale 202 typifies the moisture content and weight desired for this test and was cured successfully. Bale 222, at 19.5 percent moisture content and 60 pounds, could be expected to cure with no mold even without chemical treatment.

Taking a large number of samples for comparison can serve as a stabilizing effect, even when individual samples are not entirely accurate. For this reason, the tests con-

ducted were considered indications of the effects of the chemicals and the method of application.

The three chemicals, applied in water solution before mowing, yielded results similar to those obtained by Richards (24) in 1951.

## Second Cutting Tests

Reevaluation of objectives. The objectives of the second cutting tests were to study various application rates and methods of applying Dowicide 2S and propionic acid.

During the period between hay cuttings, a conference was held with representatives of the Dow Chemical Company. The discussion centered upon the correct chemical to use in view of the experiments already conducted, and the first-hand knowledge of the Dow Chemical Company.

Although fair results had been obtained with the use of Dowicide B and Dowicide A, the difficulties encountered in application were great enough to disqualify them for further experimentation. Both Dowicide B and Dowicide A were difficult to get into solution and caused pump screen clogging. Representatives of Dow Chemical Company felt that Dowicide A and Dowicide B did not have sufficient mold inhibiting qualities in comparison to other chemicals available. Dowicide 2S was recommended as the most promising, both in mold inhibiting properties and in practical price for the job intended. Mr. K. Kennedy (14) of Cornell University re-

ported the same findings in a personal communication to D. E. Wiant. Richards (24) had attempted to use Dowicide 2S with the five nozzle spray unit. Its insolubility in water, even in a caustic solution, rendered it impractical to use with this method. For this reason new methods and equipment were devised to apply Dowicide 2S to the hay.

In addition, propionic acid was chosen to further test the mold inhibiting properties of the fatty acids as described by Lewis (15).

Additional equipment. In addition to the haying equipment previously described, the following equipment was employed during the second cutting tests:

1. Bale sampler. (Figs. 4, 5, and 6)

2. Crop preservative dust dispenser mounted on baler. (Fig. 7)

3. Greenhouse[1] duster mounted on baler. (Fig. 8)

4. Single nozzle bale chamber spray unit mounted on baler. (Figs. 9 and 10)

5. Three nozzle apron spray unit mounted on baler. (Fig. 12)

Procedure for second cutting tests. The general procedure previously described was followed with two important

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[1] A power duster manufactured for use within a greenhouse.

exceptions:

1. The chemical mold inhibitors were added at the time of baling.

2. Each bale was sampled for moisture content determination immediately before being placed in storage.

In analyzing the haying operation to determine the most advantageous point to place the chemical on the hay, a number of factors were considered.

Before the hay is cut, water solutions may be added without damage to the crop. The major disadvantage of this method, disregarding mechanical and solution problems, is one of chemical loss by volatilization during the drying period. Lewis (16) concluded that the acids applied before mowing were reduced to ineffectual concentrations by the time the hay was baled and stored.

After the hay has been cut and rapid drying is desired, it is no longer advisable to add moisture. The chemical in other than a water solution, however, could be added during the succeeding raking and baling operations. The side delivery rake does not present an adequate support for experimental equipment and even during the period after raking much of the chemical could be lost by volatilization.

Applying the chemical at the time of baling promotes the chance of maximum beneficial return from any mold inhibiting treatment. Field exposure is eliminated and any volatilization causes the atmosphere within the bales to be saturated

with chemical. Various application points for the chemical could be employed during the baling operation; 1, on the windrow before the baler; 2, on the pick up unit or the bale chamber feeding unit; 3, directly into the baling chamber as the hay is baled. Two of these points were chosen for the second cutting tests; on the feeding apron and directly into the bale chamber. The three nozzle spray unit, directly over the feeding apron, is shown in Fig. 9. The two dusting units, (Figs. 7 and 8) and the single nozzle spray unit, (Figs. 10 and 11) applied the chemical directly into the baling chamber. The opening in the top of the chamber is clearly shown in Fig. 11.

The method previously employed to determine moisture content of the test hay as baled was open to criticism. The hay used to indicate moisture content was not an actual part of the bale, but only hay adjacent to that within the bale. Sampling in this manner is distracting to the baler operator who must vary the ground speed to insure adequate feeding of the baler. Each bale cannot be sampled when the baler is operating at proper load.

A bale sampler was constructed to alleviate the difficulties encountered in field sampling and to insure more accurate moisture content determination. The sampling was done as the bales were placed in storage.

The sampler consisted of a rack to hold the bale and a polished stainless steel rotating tube which was forced

into the center of the bale. (Fig. 4) A section of band saw blade, filed with a scalloped cutting edge, was fixed to the 2 inch diameter tube. (Fig. 5) The tube was turned on the inside to accommodate one-half of the thickness of the band saw blade, making the inside diameter of the blade smaller than the inside diameter of the tube. The hay sample, as it was cut from the bale, slid into the tube more easily because of this differential in diameters. The tube was rotated by a 5/8 inch portable electric drill mounted on a sliding cradle. (Fig. 4)

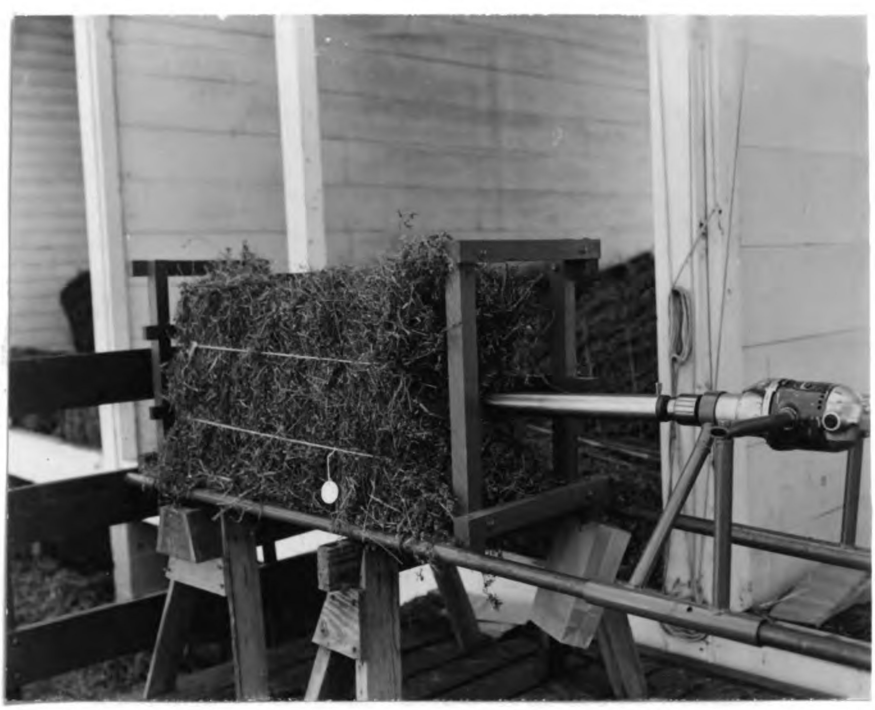

Fig. 4. Bale sampler

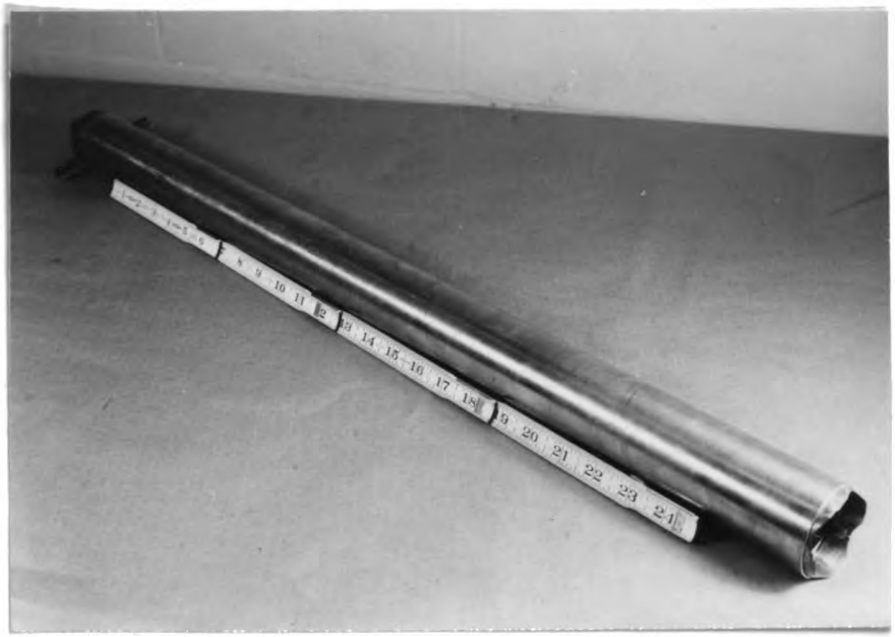

Fig. 5. Bale sampling tube

Fig. 6. Removing the sample from tube

After the sample had been cut it was pushed from the tube as shown in Fig. 6.

The bale sampler was used on all bales during the second cutting tests, to insure more accurate moisture content determination. The sample taken before the curing period was cut from only one half of the bale length, leaving the remaining one half bale to be sampled upon removal. All bales were weighed, before being placed to cure, as an indication of density.

In the procedure for the second cutting tests the effect of mow storage was eliminated as a variable by stacking the bales on end, in rows, with a space left between rows of bales. This method provided comparable storage conditions for each bale.

Dowicide 2S was used in two forms, as a dust prepared by the Dow Chemical Company, and in a solution with mineral oil. The dust, termed F1142, consisted of:

25% Dowicide 2S

10% Diluex

65% Pyrax

Both Diluex and Pyrax are trade names for inert fillers and conditioners.

Mineral oil was chosen as a solvent for Dowicide 2S because it is colorless, oderless, tasteless and harmless to livestock. Five pounds of Dowicide 2S salt were dissolved in five gallons of mineral oil. To obtain the solution one

pint of Triton X 100 was poured over the five pounds of Dowicide 2S in the mixing pail and worked into a semi-liquid state. Mineral oil was then added, mixed and poured into a five gallon container. The small amount of solid residue in the mixing pail was discarded.

Propionic acid was used undiluted, directly as received from the Bacteriology Department, Michigan State College.

Crop preservative dispenser with Dow dust F-1142. The F-1142 dust was applied directly into the bale chamber by the crop preservative dispenser, (Fig. 7) at application rates sufficient to add 2, 3 and 4 pounds of Dowicide 2S per ton of 30 percent moisture content hay. A control lot was baled with no chemical treatment.

Fig. 7. Crop preservative dust dispenser mounted on baler.

The dust dropped under force of gravity into the bale chamber and into the hay as it was baled. A bale was broken open during each run to determine the coverage pattern. Most of the dust was found to be deposited in the upper one fourth of the bale and occasionally along the top where it was easily blown off. Some of the dust did filter down to the lower portion of the bale during the two heaviest application rates.

The baling, sampling and storage procedure was conducted August 20, 1952. The bales cured until October 1, 1952 when they were removed from storage, sampled, reweighed and graded. Professor H. R. Pettigrove graded each bale. According to Professor Pettigrove little of this hay could grade higher than U.S. 3 due to the natural field color.

Table VIII A-D shows the results obtained from the three application rates and one control lot.

The most successfully cured bales were included in run 3, Table VIII-C. With an application rate of Dowicide 2S of four pounds per ton of hay, seven of the twelve bales were free of must and mold. Two of the remaining bales were only very slightly musty and three were musty.

Comparing the control lot with run 3, four of the twelve bales were free of must and mold. Seven of the remaining bales were musty to very musty and one was musty with some mold.

TABLE VIII-A

BALE INSPECTION DATA
PRESERVATIVE DISPENSER - RUN ONE
APPLICATION - 2 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 23.9 | 59 | 16.0 | 51.0 | SAMPLE Alfalfa-slightly musty. |
| 2 | 26.0 | 56 | 15.6 | 49.0 | SAMPLE Alfalfa-one end of bale very slightly musty. |
| 3 | 26.3 | 51 | 17.9 | 43.0 | SAMPLE Alfalfa-very slightly musty. |
| 4 | 25.5 | 62 | 13.6 | 54.0 | SAMPLE Alfalfa-very slightly musty two flakes. |
| 5 | 26.2 | 56 | 14.8 | 47.0 | 3 Alfalfa-color. |
| 6 | 32.2 | 55 | 13.7 | 46.0 | SAMPLE Alfalfa-very slightly musty one flake. |
| 7 | 27.1 | 59 | 16.4 | 51.0 | SAMPLE Alfalfa-musty. |
| 8 | 37.0 | 70 | 18.1 | 52.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 9 | 25.2 | 62 | 14.4 | 53.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 10 | 29.2 | 60 | 17.2 | 49.0 | SAMPLE Alfalfa-light grass mix, musty. |

TABLE VIII-A

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 11 | 28.1 | 62 | 14.2 | 51.0 | 3 Alfalfa-light grass mix, color. |
| 12 | 27.1 | 59 | 14.2 | 59.0 | 3 Alfalfa-color. |
| 13 | 25.2 | 62 | 13.7 | 52.0 | SAMPLE Alfalfa-one end of bale slightly musty. |
| 14 | 24.6 | 70 | 14.5 | 59.0 | SAMPLE Alfalfa-slightly musty. |
| 15 | 35.5 | 71 | 14.5 | 61.0 | SAMPLE Alfalfa-musty. |
| Ave. | 27.5 | 61 | | | 3 U.S. 3 |
| Range | 23.9-37.0 | 51-71 | | | 12 U.S. SAMPLE Very slightly musty to musty. |

TABLE VIII-B

BALE INSPECTION DATA
PRESERVATIVE DISPENSER - RUN TWO
APPLICATION - 3 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 25.0 | 58 | 15.8 | 50.0 | SAMPLE Alfalfa-very slightly musty. |
| 2 | 22.4 | 54 | 19.0 | 46.0 | SAMPLE Alfalfa-slightly musty. |
| 3 | 23.5 | 58 | 14.9 | 49.0 | SAMPLE Alfalfa-slightly musty one end of bale. |
| 4 | 22.2 | 60 | 18.1 | 50.0 | SAMPLE Alfalfa-slightly musty. |
| 5 | 22.0 | 59 | 17.3 | 59.0 | 3 Alfalfa-color. |
| 6 | 21.9 | 57 | 17.4 | 49.0 | SAMPLE Alfalfa-very slightly musty two flakes. |
| 7 | 21.7 | 58 | 15.2 | 49.0 | SAMPLE Alfalfa-very slightly musty two flakes. |
| 8 | 25.7 | 59 | 16.5 | 52.0 | 3 Alfalfa-color. |
| 9 | 23.4 | 55 | 16.8 | 46.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 10 | 26.1 | 62 | 17.7 | 62.0 | SAMPLE Alfalfa-musty. |

TABLE VIII-B

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 11 | 22.8 | 57 | 16.0 | 57.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 12 | 22.4 | 54 | 17.2 | 47.0 | 3 Alfalfa-color. |
| 13 | 25.0 | 61 | - | 52.0 | 3 Alfalfa-color. |
| 14 | 29.2 | 61 | 16.3 | 50.0 | SAMPLE Alfalfa-light grass mix, very slightly musty two flakes. |
| Ave. | 23.8 | 58 | | | 4 U.S. 3 |
| Range | 21.7-29.2 | 54-62 | | | 10 U.S. SAMPLE Very slightly musty to musty. |

TABLE VIII-C

BALE INSPECTION DATA
PRESERVATIVE DISPENSER - RUN THREE
APPLICATION - 4 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 20.0 | 42.5 | 14.7 | 36.0 | 3 Alfalfa-color. |
| 2 | 20.9 | 47.5 | 13.8 | 41.0 | 3 Alfalfa-color. |
| 3 | 23.2 | 48.0 | 14.7 | 41.5 | 3 Alfalfa-color. |
| 4 | 24.6 | 52.0 | 16.2 | 45.0 | 3 Alfalfa-color. |
| 5 | 24.9 | 60.0 | 16.4 | 51.0 | SAMPLE Alfalfa-very slightly musty one flake. |
| 6 | 22.6 | 58.0 | 15.6 | 48.0 | SAMPLE Alfalfa-very slightly musty one flake. |
| 7 | 24.7 | 56.0 | 16.7 | 49.0 | SAMPLE Alfalfa-slightly musty. |
| 8 | 23.0 | 55.0 | 15.9 | 46.0 | 3 Alfalfa-color. |
| 9 | 26.0 | 55.0 | 12.8 | 44.0 | SAMPLE Alfalfa-musty. |
| 10 | 23.3 | 55.0 | 14.2 | 45.0 | SAMPLE Alfalfa-musty. |
| 11 | 29.0 | 52.0 | 15.6 | 44.0 | 3 Alfalfa-color. |

TABLE VIII-C

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 12 | 25.4 | 54.0 | 15.2 | 47.0 | 3 Alfalfa-color. |
| Ave. | 24.0 | 53.0 | | | 7 U.S. 3 |
| Range | 20.0-29.0 | 54-62 | | | 5 U.S. SAMPLE Very slightly musty one flake to musty. |

TABLE VIII-D

BALE INSPECTION DATA
PRESERVATIVE DISPENSER - CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 26.4 | 47.0 | 13.5 | 39.0 | 3 Alfalfa-color. |
| 2 | 20.5 | 75.0 | 13.4 | 57.0 | SAMPLE Alfalfa-musty. |
| 3 | 21.4 | 46.0 | 12.7 | 38.0 | 3 Alfalfa-color. |
| 4 | 25.3 | 42.0 | 14.3 | 35.0 | 3 Alfalfa-color. |
| 5 | 37.4 | 73.5 | 16.7 | 50.0 | SAMPLE Alfalfa-musty, little moldy. |
| 6 | 25.6 | 59.0 | 13.1 | 46.0 | SAMPLE Alfalfa-musty. |
| 7 | 27.6 | 68.0 | 16.1 | 55.0 | SAMPLE Alfalfa-musty. |
| 8 | 25.3 | 66.0 | 15.4 | 54.0 | SAMPLE Alfalfa-very musty. |
| 9 | 32.0 | 61.0 | 16.4 | 48.0 | SAMPLE Alfalfa-very musty. |
| 10 | 23.6 | 57.0 | 12.4 | 48.5 | SAMPLE Alfalfa-very slightly musty two flakes. |
| 11 | 26.5 | 51.0 | 14.4 | 42.0 | SAMPLE Alfalfa-musty. |

TABLE VIII-D

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 12 | 22.7 | 58.0 | 14.7 | 49.0 | 3 Alfalfa-color. |
| Ave. | 26.2 | 59.0 | | | 4 U.S. 3 |
| Range | 20.5-37.4 | 42-75 | | | 7 U.S. SAMPLE Very slightly musty two flakes to very musty.<br>1 U.S. SAMPLE Musty, little moldy. |

An improvement in quality was obtained through the use of Dow dust F-1142 with the crop preservative dispenser. Complete control of must was not attained. One bale of the control lot contained visible mold.

Mounted greenhouse duster with Dow F-1142. In an attempt to obtain more complete coverage within the bale using the Dow dust F-1142, a greenhouse duster was employed. (Fig. 8) Air blast for the duster is provided by a gasoline engine powered centrifugal fan.

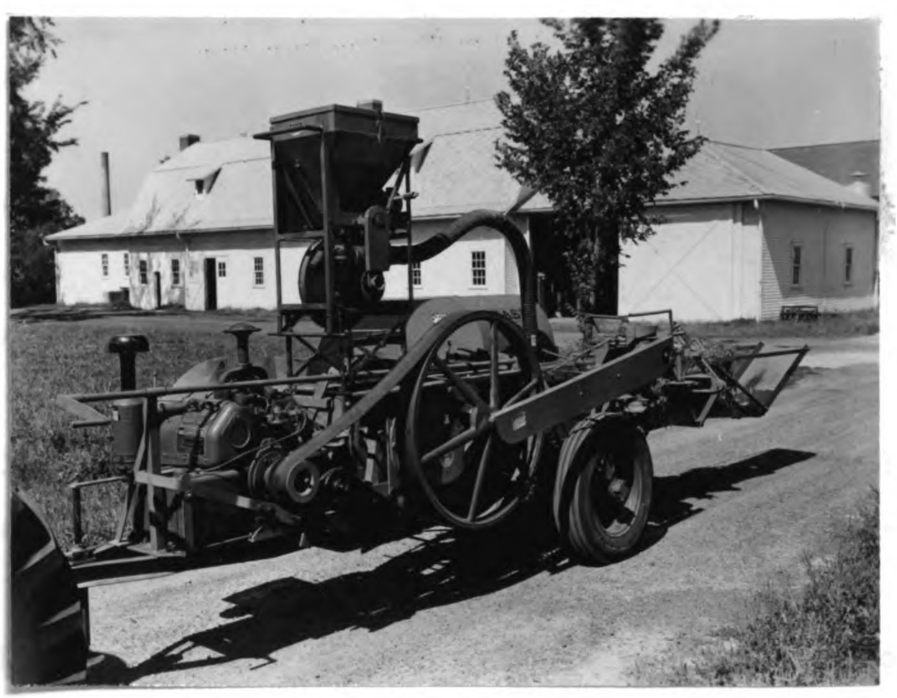

Fig. 8. Greenhouse duster mounted on baler.

Four application rates of F-1142 were used with the resulting rates of Dowicide 2S:

1. 4.85 pounds per ton
2. 5.41 pounds per ton
3. 7.38 pounds per ton
4. 7.36 pounds per ton

To obtain these figures, the duster was calibrated in terms of output per minute, each run was timed, the bales were weighed and hay tonnage corrected to 30 percent moisture content. No allowance was made for losses due to incomplete recovery.

During the baling operation, the duster produced an objectionable cloud of dust in the area surrounding the baler.

Inspection of one bale of each run during baling showed the dust was being distributed through the bale by the air blast. The concentration was again heaviest at the top but more adequate distribution was accomplished than with the crop preservative dispenser.

The bales were placed in storage August 25, 1952 and removed for inspection October 1, 1952. Table IX A-E contains the data for each bale.

Each run of the treated bales were in better condition upon inspection than the control run. All of the fifteen control bales contained must and mold. Bales in run 3 and run 4 received approximately the same treatment and graded similarly. The eleven bales of run 3 contained two U.S. 2

TABLE IX-A

BALE INSPECTION DATA
GREENHOUSE DUSTER - RUN ONE
APPLICATION - 4.85 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 30.4 | 47.0 | 9.3 | 41.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 2 | 23.5 | 46.0 | 8.4 | 42.0 | 2 Alfalfa-light grass mix, color. Bale dense on one side, thin on other due to way hay went into baler. |
| 3 | 25.0 | 45.0 | 10.5 | 44.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 4 | 30.4 | 59.0 | 10.4 | 50.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 5 | 28.0 | 64.0 | 7.6 | 51.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 6 | 30.1 | 64.0 | 12.9 | 51.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 7 | 37.2 | 79.0 | 5.2 | 55.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 8 | 26.1 | 50.0 | 16.8 | 49.0 | SAMPLE Alfalfa-light grass mix, very slightly musty. |
| 9 | 27.5 | 52.0 | 13.6 | 45.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |

TABLE IX-A

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 35.8 | 65.0 | 10.0 | 49.5 | SAMPLE Alfalfa-light grass mix, musty. One-half of bale moldy. |
| 11 | 29.1 | 58.0 | 6.7 | 46.5 | SAMPLE Alfalfa-light grass mix, musty. |
| 12 | 36.9 | 54.0 | 12.5 | 39.5 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 13 | 40.2 | 73.0 | 10.9 | 49.0 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. Mold distinct through out the bale. |
| 14 | 32.4 | 52.0 | 12.5 | 39.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 15 | 23.5 | 45.0 | 12.2 | 39.0 | SAMPLE Alfalfa-light grass mix, one flake slightly musty. |
| 16 | 33.6 | 59.0 | 11.4 | 48.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| Ave. | 30.6 | 57.0 | | | 1 U.S. 2 |
| Range | 23.5-40.2 | 45-79 | | | 11 U.S. SAMPLE Very slightly musty to musty.<br>4 U.S. SAMPLE Musty, moldy. |

TABLE IX-B

BALE INSPECTION DATA
GREENHOUSE DUSTER - RUN TWO
APPLICATION - 5.41 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 30.2 | 63.0 | 14.1 | 43.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 2 | 22.1 | 59.0 | 14.7 | 45.5 | ——— |
| 3 | 31.3 | 70.0 | 13.6 | 52.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 4 | 28.0 | 59.0 | 11.5 | 49.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 5 | 31.6 | 59.0 | 16.7 | 44.0 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. |
| 6 | 25.6 | 58.0 | 12.0 | 50.5 | SAMPLE Alfalfa-light grass mix, very slightly musty in central flakes of bale. |
| 7 | 27.7 | 55.0 | 14.6 | 46.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 8 | 26.7 | 55.0 | 14.3 | 45.5 | SAMPLE Alfalfa-light grass mix, musty. |
| 9 | 27.9 | 56.0 | ——— | ——— | ——— |

TABLE IX-B

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 26.0 | 58.0 | 13.8 | 48.5 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| Ave. | 27.7 | 59.0 | | | 7 U.S. SAMPLE Very slightly musty to musty. |
| Range | 22.1-31.6 | 55-70 | | | 1 U.S. SAMPLE Musty, moldy. |

TABLE IX-C

BALE INSPECTION DATA
GREENHOUSE DUSTER - RUN THREE
APPLICATION - 7.38 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 30.2 | 62.0 | 14.9 | 43.5 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 2 | 32.7 | 69.0 | 14.9 | 58.0 | SAMPLE Alfalfa-light grass mix, very slightly musty. |
| 3 | 34.0 | 74.0 | 16.7 | 52.5 | SAMPLE Alfalfa-light grass mix, very slightly musty. |
| 4 | 22.5 | 59.0 | 14.3 | 51.5 | 2 Alfalfa-light grass mix, color. |
| 5 | 27.6 | 62.0 | 14.0 | 53.5 | SAMPLE Alfalfa-light grass mix, very slightly musty and an area of yellow mold. |
| 6 | 25.4 | 60.0 | 15.6 | 46.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 7 | 32.5 | 67.0 | 12.5 | 55.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 8 | 32.9 | 59.0 | 12.2 | 45.5 | SAMPLE Alfalfa-heavy grass mix, very slightly musty. |
| 9 | 30.3 | 54.0 | 13.1 | 45.0 | 2 Alfalfa-light grass mix, color. |

TABLE IX-C

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 36.0 | 72.0 | 10.5 | 55.0 | SAMPLE Alfalfa-light grass mix, musty and a little mold scattered through the bale. |
| 11 | 32.2 | 67.0 | 12.4 | 54.0 | SAMPLE Alfalfa-light grass mix, musty. |
| Ave. | 30.6 | 64.0 | | | 2 U.S. 2 |
| Range | 22.5-36.0 | 54-74 | | | 7 U.S. SAMPLE Very slightly musty to musty.<br>2 U.S. SAMPLE Musty, little moldy. |

TABLE IX-D

BALE INSPECTION DATA
GREENHOUSE DUSTER - RUN FOUR
APPLICATION - 7.36 LB. DOWICIDE 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 36.8 | 66.0 | 11.6 | 49.0 | SAMPLE Alfalfa-light grass mix, musty,, moldy,, extra leafy. |
| 2 | 35.3 | 59.0 | 13.9 | 45.0 | SAMPLE Alfalfa-light grass mix, musty, extra leafy. |
| 3 | 28.6 | 61.0 | 9.8 | 52.0 | 2 Alfalfa-light grass mix, color,, extra leafy. |
| 4 | 29.7 | 68.0 | 8.6 | 57.0 | 2 Alfalfa-light grass mix, color, extra leafy. |
| 5 | 27.5 | 64.0 | 10.4 | 51.5 | SAMPLE Alfalfa-light grass mix, slightly musty, extra leafy. |
| 6 | 34.6 | 69.0 | 12.0 | 51.5 | SAMPLE Alfalfa-light grass mix, musty and white mold scattered through bale. Extra leafy. |
| 7 | 29.1 | 66.0 | 10.6 | 51.0 | SAMPLE Alfalfa-heavy grass mix, musty, extra leafy. |

TABLE IX-D

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 8 | 33.6 | 63.0 | 10.9 | 48.0 | SAMPLE Alfalfa-light grass mix, musty, and moldy, especially one end of bale. Extra leafy. |
| 9 | 28.6 | 63.0 | 11.4 | 52.0 | SAMPLE Alfalfa-light grass mix, slightly musty in two or three of center flakes, extra leafy. |
| Ave. | 31.5 | 64.0 | | | 2 U.S. 2 |
| Range | 27.5-36.8 | 59-69 | | | 4 U.S. SAMPLE Slightly musty to musty.<br>3 U.S. SAMPLE Musty, moldy. |

TABLE IX-E

BALE INSPECTION DATA
GREENHOUSE DUSTER - CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 28.1 | 59.0 | 10.2 | 47.5 | SAMPLE Alfalfa-light grass mix, musty, slightly moldy. |
| 2 | 30.3 | 68.0 | 9.8 | 47.5 | SAMPLE Alfalfa-light grass mix, musty and moldy. |
| 3 | 30.4 | 56.0 | 10.2 | 40.0 | SAMPLE Alfalfa-light grass mix, musty and moldy. |
| 4 | 26.3 | 63.0 | 11.0 | 48.0 | SAMPLE Alfalfa-light grass mix, musty and slightly moldy. |
| 5 | 27.4 | 66.0 | 11.4 | 48.5 | SAMPLE Alfalfa-light grass mix, musty and moldy. |
| 6 | 27.3 | 65.0 | 49.5 | 10.0 | SAMPLE Alfalfa-light grass mix, very musty. |
| 7 | 32.3 | 61.0 | 12.2 | 42.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 8 | 32.2 | 63.0 | 9.3 | 46.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, yellow gray, mold is scattered throughout the bale. |

TABLE IX-E

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 9 | 30.6 | 59.0 | 9.3 | 47.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 10 | 28.0 | 59.0 | 9.9 | 46.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 11 | 30.0 | 57.0 | 9.7 | 42.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 12 | 28.9 | 63.0 | 10.1 | 47.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 13 | 31.7 | 78.0 | 11.2 | 56.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |

TABLE IX-E

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 14 | 26.9 | 65.0 | 11.3 | 49.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, color is much more yellow gray, mold is scattered throughout the bale. |
| 15 | 33.5 | 78.0 | 12.4 | 55.0 | SAMPLE Alfalfa-light grass mix, musty, moldy, mold is well scattered throughout the bale. |
| Ave. | 29.6 | 64.0 | | | 15 U.S. SAMPLE Musty, moldy. |
| Range | 26.3-33.5 | 56-78 | | | |

grade, seven U.S. SAMPLE (some must) and two U.S. SAMPLE (must with some mold). Bales in run 4 graded two U.S. 2 grade, four U.S. SAMPLE (some must), and three U.S. SAMPLE (must and some mold). Although complete control of must and mold was not attained, a substantial improvement was noted in the treated bales.

The range of moisture contents was narrow throughout this test and, in general, throughout the entire second cutting tests. This was due primarily to more representative samples obtained with the bale sampler. All of the various average moisture contents were close to the desired 30 percent.

A narrow range of bale weights was also noted. A competent baler operator can regulate baler feeding to produce uniform bales provided he is free of distractions. The bale sampler provided this condition by supplanting the windrow sampling method.

Single nozzle bale chamber spray unit using propionic acid. The power take off gear pump, used with the spray boom during first cutting tests, was used with the single nozzle unit shown in Figs. 9 and 10.

To prevent spraying the baler plunger as it passed the opening in the bale chamber, a shut off device was incorporated in the spraying mechanism.

A wedge shaped piece of flat stock, welded to the valve actuating rod, extended into the bale chamber directly into

Fig. 9. Single nozzle bale chamber spray unit.

Fig. 10. Underside of bale chamber spray unit. At each stroke of the plunger the wedge is forced up, shutting off the spray.

the path of the baler plunger. (Fig. 10) The actuating rod was forced upward as the bale plunger came in contact with the wedge shaped piece. As the baler plunger returned to admit more hay into the chamber, the actuating rod was forced down into the chamber by the spring loaded lever. (Fig. 9) The cycle was repeated at each stroke of the baler plunger.

Propionic acid is highly volatile, and the atmosphere surrounding the baler was saturated with the fumes during the time it was being sprayed. Its odor, however, was not objectionable.

As the first bales containing the acid were formed, the paint softened and was scoured from the inside of the bale chamber. Combined with hay of high moisture content, this scouring caused extremely dense bales to be formed. The approximate application rate was five gallons per ton of hay. An inspection of one bale showed the acid to be in all parts of the bale with the heaviest application in the top near the nozzle discharge.

Baling took place on August 23, 1952 and the bales were placed in storage that evening. The bales were removed and inspected October 1, 1952. Table X A-B contains the test bale data.

Upon inspection, the control bales were found to be in better condition than the treated bales. Of the ten treated bales only one was free of mold and of the untreated

TABLE X-A

BALE INSPECTION DATA
CHAMBER SPRAY PROPIONIC ACID - RUN ONE
APPLICATION - 5 GAL. PROPIONIC ACID/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 37.8 | 47.0 | 9.8 | 68.5 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 2 | 34.5 | 94.0 | 9.6 | 69.0 | SAMPLE Alfalfa-musty, moldy. |
| 3 | 44.3 | 92.0 | 12.5 | 61.0 | SAMPLE Alfalfa-musty, very moldy. |
| 4 | 33.8 | 72.0 | 10.1 | 56.5 | SAMPLE Alfalfa-musty, moldy. |
| 5 | 33.3 | 99.0 | 11.1 | 77.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 6 | 33.0 | 88.0 | 10.1 | 71.5 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 7 | 28.4 | 45.0 | 10.8 | 37.5 | SAMPLE Alfalfa-heavy grass mix, slightly musty one end of bale; otherwise good. |
| 8 | 29.6 | 63.0 | 11.3 | 53.0 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. Can still smell the acid slightly. |
| 9 | 40.1 | 95.0 | 10.4 | 71.5 | SAMPLE Alfalfa-light grass mix, musty, moldy. |

TABLE X-A

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 35.3 | 92.0 | 10.5 | 68.0 | SAMPLE Alfalfa-light grass mix, musty, very moldy. |
| Ave. | 35.0 | 79.0 | | | 1 U.S. SAMPLE Slightly musty. |
| range | 28.4-40.1 | 45-99 | | | 9 U.S. SAMPLE Musty and moldy. |

TABLE X-B

BALE INSPECTION DATA
CHAMBER SPRAY PROPIONIC ACID - CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 31.5 | 52.0 | 10.3 | 41.5 | SAMPLE Alfalfa-heavy grass mix, musty. |
| 2 | 25.3 | 54.0 | 11.0 | 44.0 | SAMPLE Alfalfa-heavy grass mix, musty. |
| 3 | 33.8 | 66.0 | 9.7 | 50.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 4 | 27.7 | 66.0 | 11.3 | 53.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 5 | 33.3 | 68.0 | 12.0 | 51.0 | SAMPLE Alfalfa-musty, slightly moldy. |
| 6 | 31.5 | 75.0 | 10.5 | 57.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 7 | 29.6 | 76.0 | 11.3 | 61.0 | SAMPLE Alfalfa-heavy grass mix, musty,. slightly moldy. |
| 8 | 29.7 | 78.0 | 12.5 | 60.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 9 | 32.5 | 69.0 | 11.3 | 50.0 | SAMPLE Alfalfa-light grass mix, musty. |

TABLE X-B

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 27.7 | 76.0 | 13.9 | 57.5 | SAMPLE Alfalfa-light grass mix, musty. |
| 11 | 29.3 | 83.0 | 11.1 | 61.0 | SAMPLE Alfalfa-musty, slightly moldy. |
| Ave. | 30.2 | 69.0 | | | 8 U.S. SAMPLE Musty. |
| Range | 25.3-33.8 | 52-83 | | | 3 U.S. SAMPLE Musty, slightly moldy. |

bales eight of eleven were free of mold. All bales were found to contain must. Examination of the respective average moisture contents and bale weights as placed in storage reveals the cause of the poor showing of the treated bales. Average moisture contents were 35.0 percent and 30.2 percent respectively for the treated and control bales. Average weights were 79 pounds and 69 pounds respectively.

Chamber spray unit with Dowicide 2S in mineral oil. The chamber spray unit (Figs. 9 and 10) was used with the solution of Dowicide 2S in mineral oil previously described.

Hay in this test was treated at the rate of 3.5 pounds of Dowicide 2S per ton. Baling took place during the afternoon of August 24, 1952 and sampling, weighing and placing in storage that evening. The bales were inspected with the other tests on October 1, 1952. Test bale data and grades as assigned by Professor Pettigrove are shown in Table XI A-B.

The treated bales were in better condition upon removal, although none were free of must. One contained a little mold. Bales in the control lot contained more must than those treated and two contained mold.

As an example of the problem encountered with the use of mold inhibitors, Fig. 11 shows a slice of hay removed from one of the treated bales. The oil solution of Dowicide 2S had covered a section along the upper edge and a section vertically through the slice. No mold or must occurred in

TABLE XI-A

BALE INSPECTION DATA
CHAMBER SPRAY DOWICIDE 2S - RUN ONE
APPLICATION - 2.5 LB. 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 29.5 | 62.0 | 9.3 | 49.0 | SAMPLE Alfalfa-heavy grass mix, musty. |
| 2 | 29.5 | 61.0 | 9.7 | 49.0 | SAMPLE Alfalfa-musty. |
| 3 | 27.3 | 68.0 | 6.9 | 52.5 | SAMPLE Alfalfa-musty. |
| 4 | 34.3 | 65.0 | 10.7 | 47.0 | ——— |
| 5 | 30.8 | 65.0 | 13.3 | 47.0 | SAMPLE Alfalfa-musty. |
| 6 | 32.4 | 72.0 | 8.5 | 50.5 | SAMPLE Alfalfa-musty. |
| 7 | 34.5 | 58.0 | 11.9 | 42.0 | SAMPLE Alfalfa-musty. |
| 8 | 30.3 | 69.0 | ——— | ——— | SAMPLE Alfalfa-heavy grass mix, musty and a little mold showing up in the bale. |
| 9 | 29.6 | 60.0 | 11.8 | 47.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 10 | 34.0 | 69.0 | 10.3 | 52.0 | SAMPLE Alfalfa-heavy grass mix, slightly musty,. where the mineral oil appeared to be over the entire flake of the bale, there appeared to be no must. |

TABLE XI-A

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 11 | 27.0 | 60.0 | —— | 9.1 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| Ave. | 30.8 | 64.0 | | | 9 U.S. SAMPLE Slightly musty to musty. |
| Range | 27.0-34.5 | 58-72 | | | 1 U.S. SAMPLE Musty and little moldy. |

TABLE XI-B

BALE INSPECTION DATA
CHAMBER SPRAY DOWICIDE 2S - CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 26.4 | 54.0 | 12.4 | 41.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 2 | 27.3 | 47.5 | 11.9 | 38.0 | SAMPLE Alfalfa-light grass mix, slightly musty. |
| 3 | 25.0 | 57.5 | 13.8 | 43.0 | SAMPLE Alfalfa-heavy grass mix, musty. |
| 4 | 28.4 | 49.0 | 15.3 | 38.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 5 | 25.5 | 52.0 | 13.1 | 40.0 | SAMPLE Alfalfa-light grass mix, musty. |
| 6 | 25.7 | 53.0 | 42.0 | 13.0 | SAMPLE Alfalfa-light grass mix, very musty. |
| 7 | 31.6 | 43.0 | 16.1 | 36.5 | SAMPLE Alfalfa-light grass mix, very musty. |
| 8 | 26.9 | 50.0 | 16.2 | 38.0 | SAMPLE Alfalfa-light grass mix, very musty. |
| 9 | 31.8 | 53.0 | 13.3 | 41.0 | SAMPLE Alfalfa-heavy grass mix, musty, slightly moldy. |

TABLE XI-B

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 10 | 24.4 | 49.0 | 8.2 | 39.5 | SAMPLE Alfalfa-heavy grass mix, musty. |
| 11 | 36.1 | 50.0 | 9.4 | 37.5 | SAMPLE Alfalfa-heavy grass mix, musty moldy. |
| 12 | 24.0 | 50.0 | 12.7 | 41.0 | SAMPLE Alfalfa-heavy grass mix, musty. |
| Ave. | 27.8 | 51.0 | | | 10 U.S. SAMPLE Musty to very musty. |
| Range | 24.0-36.1 | 47.5-57.5 | | | 2 U.S. SAMPLE Musty, moldy. |

the area thus covered; however, immediately surrounding the area covered with Dowicide 2S, must occurred. In Fig. 11 the outer portion on each side may be seen to be lighter in color where the must developed.

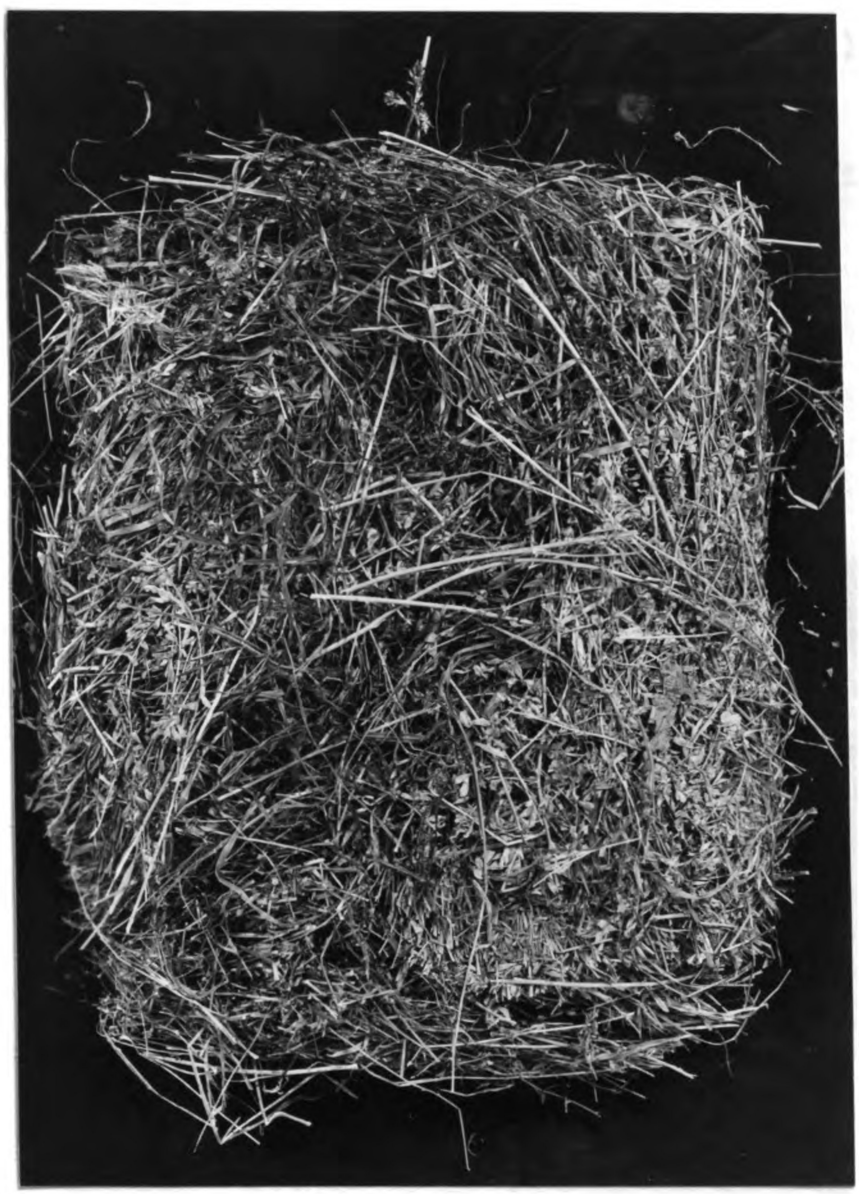

Fig. 11. Typical distribution pattern obtained with single nozzle bale chamber unit.

This revelation completely disqualified any theory that if a portion of the bale was treated the compound would diffuse throughout the bale and inhibit mold growth.

Three nozzle apron spray unit with Dowicide 2S in mineral oil. In an attempt to obtain more complete coverage of the hay with the mold inhibitor material, a three nozzle apron spray unit was constructed. (Fig. 12) Three runs of treated bales and a control lot were baled and placed in storage August 28, 1952. The three application rates of Dowicide 2S were:

3.25 lb. per ton

2.63 lb. per ton

3.73 lb. per ton


Fig. 12. Three nozzle apron spray unit

The nozzles used, on the boom extending over the bale apron, atomized the compound as it was sprayed on the hay. The atmosphere surrounding the baler was saturated with the compound, which is not desirable. Dowicide 2S, in particular, may irritate the skin if deposited and rubbed into the pores.

Table XII A-D contains the data for each bale and the result of the bale inspection.

All of the untreated bales contained must and mold, with two described as "very musty and very moldy". Of the seven bales in run 1, treatment 3.25 pounds 2S per ton, all contained mold. Seven of eight in both run 2, treatment 2.63 pounds 2S per ton, and run 3, treatment 3.73 pounds 2S per ton, contained mold.

TABLE XII-A

BALE INSPECTION DATA
APRON SPRAY DONICIDE 2S - RUN ONE
APPLICATION - 3.25 LB. 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 28.4 | 60.0 | 18.4 | 54.0 | SAMPLE Alfalfa-light grass mix, one half bale musty, moldy, yellow and others. |
| 2 | 27.0 | 58.0 | 16.5 | 51.0 | SAMPLE Alfalfa-light grass mix, very slightly musty, slightly moldy. (Light color) |
| 3 | 25.4 | 59.0 | 19.2 | 50.0 | SAMPLE Alfalfa-light grass mix, musty, yellow and dark mold. |
| 4 | 26.3 | 58.0 | 20.8 | 52.0 | SAMPLE Alfalfa-light grass mix, musty, yellow and dark mold. |
| 5 | 26.1 | 66.0 | 19.0 | 55.0 | SAMPLE Alfalfa-light grass mix, slightly musty, yellow and dark mold. |
| 6 | 23.8 | 76.0 | 18.1 | 65.0 | SAMPLE Alfalfa-slightly musty, slightly moldy, mostly dark, some white. |

TABLE XII-A

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 7 | 22.9 | 62.0 | 17.5 | 56.0 | SAMPLE Alfalfa-yellow mold, no musty odor. |
| Ave. | 26.4 | 63.0 | | | 7 U.S. SAMPLE Musty, slightly moldy. |
| Range | 22.9-28.8 | 58-76 | | | |

TABLE XII-B

BALE INSPECTION DATA
APRON SPRAY DOWICIDE 2S - RUN TWO
APPLICATION - 2.63 LB. 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 27.3 | 57.0 | 49.5 | 22.6 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 2 | 26.4 | 59.0 | 21.5 | 50.5 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 3 | 24.8 | 58.0 | 19.4 | 52.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 4 | 27.7 | 52.0 | 23.3 | 47.5 | SAMPLE Alfalfa-light grass mix, slightly musty, slightly moldy. |
| 5 | 30.1 | 68.0 | 18.9 | 56.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 6 | 34.2 | 57.0 | 19.1 | 45.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 7 | 24.4 | 47.0 | 21.2 | 42.5 | 3 Alfalfa-light grass mix, color. |
| 8 | 26.5 | 52.0 | 20.0 | 47.0 | SAMPLE Alfalfa-light grass mix, slightly musty, blue mold two flakes. |
| Ave. | 27.7 | 56.0 | | | 1 U.S. 3 |
| Range | 24.4-34.2 | 47-68 | | | 7 U.S. SAMPLE Musty, moldy. |

TABLE XII-C

BALE INSPECTION DATA
APRON SPRAY DOWICIDE 2S - RUN THREE
APPLICATION - 3.73 LB. 2S/TON

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 26.1 | 54.0 | 25.9 | 46.0 | SAMPLE Alfalfa-light grass mix, slightly musty, slightly moldy. |
| 2 | 25.0 | 57.0 | 19.2 | 51.0 | SAMPLE Alfalfa-light grass mix, slightly musty, slightly moldy. |
| 3 | 25.0 | 59.0 | 27.7 | 50.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 4 | 29.7 | 58.0 | 18.7 | 46.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 5 | 29.8 | 59.0 | 19.6 | 48.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 6 | 27.3 | 49.0 | 21.3 | 44.0 | SAMPLE Alfalfa-light grass mix, very slight musty, very slightly moldy. |
| 7 | 26.2 | 57.0 | 18.8 | 50.0 | SAMPLE Alfalfa-light grass mix, slightly musty, slightly moldy. |

TABLE XII-C

(CONTINUED)

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 8 | 20.2 | 56.0 | 20.7 | 52.0 | 3 Alfalfa-light grass mix, color. |
| Ave. | 26.2 | 56.0 | | | 1 U.S. 3 |
| Range | 20.2-29.8 | 49-59 | | | 7 U.S. SAMPLE Very slightly musty and very slightly moldy to musty-moldy. |

TABLE XII-D

BALE INSPECTION DATA
APRON SPRAY DOWICIDE 2S - CONTROL
APPLICATION - NONE

| Bale No. | Moisture Content in-% | Weight in-lb. | Moisture Content out-% | Weight out-lb. | U.S. Grade |
|---|---|---|---|---|---|
| 1 | 22.8 | 51.5 | 18.8 | 40.5 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. |
| 2 | 32.2 | 53.0 | 18.5 | 43.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 3 | 28.0 | 56.0 | 19.5 | 43.0 | SAMPLE Alfalfa-heavy grass mix, very musty, very moldy. |
| 4 | 25.5 | 57.0 | 19.5 | 46.5 | SAMPLE Alfalfa-light grass mix, very musty, very moldy. |
| 5 | 26.7 | 63.0 | 25.5 | 49.5 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. |
| 6 | 22.6 | 50.0 | 21.1 | 43.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 7 | 25.2 | 56.0 | 24.4 | 46.0 | SAMPLE Alfalfa-light grass mix, musty, moldy. |
| 8 | 28.6 | 52.0 | 23.1 | 42.0 | SAMPLE Alfalfa-heavy grass mix, musty, moldy. |
| Ave. | 26.5 | 55.0 | | | 8 U.S. SAMPLE Musty, moldy to very musty, very moldy. |
| Range | 22.6-32.2 | 51.5-63 | | | |

Fig. 13 is a close up view of the edge of a typical treated bale in this test. After the hay had been sprayed with the mold inhibitor, the baler plunger sliced off the edge of the bale with each stroke. Untreated surfaces were then not protected from mold growth. Upon examination of Fig. 13 mold can be seen gathered around many of the cut stem ends. Thus mold occurred in many of the treated bales.

Fig. 13. Mold growth on stem ends which were sliced after treatment.

## Discussion of Results

Although complete control of must was not attained throughout the various tests, the treated bales were in better condition than the untreated bales. Mold was controlled in a large majority of the treated bales.

The first cutting tests yielded results similar to those obtained by Richards in 1951. Dowicide B, Dowicide A, and D.H.A.S. were applied in water solution before mowing at the approximate rate of 2 pounds of chemical per ton of hay. Adequate coverage was difficult to obtain in heavy first cutting alfalfa, even when the stand was uniform in height. Dowicide A and D.H.A.S. were ineffective while Dowicide B showed promise in the Set 2 test. The mechanical and solution problems using Dowicide B with the spray boom method, however, disqualified the chemical for further investigation.

All of the tests during the second cutting employing Dowicide 2S yielded bales in better condition than the respective control bales.

Propionic acid was found to be ineffective in the concentration used. The moisture content of the hay and density of bales were higher than desirable in this test.

Considering the method employed to apply the chemical to the hay, most adequate coverage was obtained with the mounted greenhouse duster. A cloud of dust surrounding the

baler during operation of the duster was objectionable in which to work. Handling of four pounds of dust for each one pound of active material was an additional disadvantage.

The three nozzle apron spray unit produced excellent coverage on the hay before baling but the slicing action of the baler plunger exposed an untreated edge upon which mold was easily established. Spraying in the open with atomizing nozzles also produced an inhibitor saturated area surrounding the baler.

The application method which was most satisfactory to work with was the chamber spray unit. (Figs. 9 and 10) Complete coverage was not attained with the one nozzle located in the top of the baled chamber. Additional nozzles distributed over the plunger area could be employed to assure more adequate coverage of the hay within the bale.

## CONCLUSIONS

1. Complete control of must was not obtained with any of the chemicals or application methods used in the tests. Mold, however, was found in but a few of the treated bales. With the exception of two tests, all of the treated bales contained less must than the comparable control lots.

2. Spraying water soluble chemicals upon standing hay before mowing, yielded results similar to those found by previous investigators. Dowicide A and D.H.A.S. were ineffective in controlling must and mold. Dowicide B showed some beneficial effect, however, the problems of solution and screen clogging combined with the difficulty of obtaining adequate coverage, eliminated this chemical and method of application.

3. Dowicide 2S, both in dust form and in an oil solution, was effective in controlling must and mold. An application rate of 7.4 pounds of Dowicide 2S per ton of hay (assuming no loss due to incomplete recovery) with the greenhouse duster unit, resulted in but two of eleven bales with some mold, as contrasted with all fifteen of the untreated bales moldy.

Dowicide 2S in mineral oil, sprayed directly into the bale chamber at the rate of 3.5 pounds per ton of hay,

resulted in but one bale of ten containing mold and the others only slightly musty. The control lot resulted in two of the twelve bales moldy and the remaining ten very musty.

4. To obtain complete control of mold in baled hay, higher application rates of Dowicide 2S than those used are necessary.

5. Propionic acid was not effective in controlling mold growth.

6. The bale chamber spray unit was found to be the most satisfactory method of chemical mold inhibitor application. The single nozzle unit, however, did not provide adequate coverage.

7. The bale sampling unit produced excellent results with moisture content determinations by providing more representative samples.

## RECOMMENDATIONS FOR FURTHER STUDY

1. The bale chamber spray unit can be improved to provide more adequate coverage within the bale. One or more nozzles on the baler plunger may prove satisfactory.

2. Solutions containing a higher concentration of chemical mold inhibitor are needed to eliminate handling excessive amounts of solution.

3. Varied methods of stacking for curing mold inhibitor treated bales could be tested. Included would be space stacking and helter skelter with natural draft curing.

4. Mold inhibitors, Dowicide 2S in particular, could be tested in conjunction with a limited forced air system. Bales could be piled in a helter skelter manner to reduce labor costs. Although one of the objectives of mold inhibitors is the elimination of high cost forced air systems, a simple system with low air flow could increase the effectiveness of both methods. For example, the bales treated with Dowicide 2S by the three nozzle apron spray unit developed mold on the untreated cut edges. This may have been eliminated if a small amount of air could have been forced around the outside of the bales and speeded the curing of the bale edges.

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