THE RELATIVE EFFICIENCY OF SEVERAL SPRAYS FOR REPELLING STABLE FLIES ON DAIRY CATTLE IN THE FIELD AND FOR CONTROLLING HOUSE FLIES IN THE BARN

by

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GENERAL INTRODUCTION

Fly control is an important problem among all livestock men, and dairymen in particular because of the features of clean milk production. The most important thing is cleanliness. Nevertheless, some supplementary control method is needed because of the limitations of sanitary control measures under the conditions of commercial milk production. The supplementary method in common use is application of sprays to the animal as a repellent and the diffusion of spray in the barn to reduce fly numbers by killing them.

This study was initiated to determine the relative merit of different specific compounds, toxic to flies, and different combinations thereof. A new organic compound sold under the name Thanite was compared with other compounds commonly used.

The relative merit of the different compounds was measured from the standpoint of repellency when sprayed on dairy cattle in the field and from the standpoint of "knockdown and kill" when diffused in the dairy barn. Since the two studies were entirely separate approaches to the problem they are presented in two parts. The discussion of literature, data, and results for each are presented under the appropriate sections.

PART I. TESTS OF FLY REPELLENTS OF KNOWN INGREDIENTS AND SELECTED COMMERCIAL SPRAYS ON DAIRY CATTLE

PRESENTATION OF THE PROBLEM

Dairyman probably use more fly spray, certainly of the repellent type, than any other class of people. The problems of sanitary milk production, together with the more detailed handling of dairy cows, has brought this about. The dairyman not only wants a spray that will protect the cows during the milking process for the comfort of both the cow and the attendant, but he also wants a spray that will provide considerable protection over a period of time with no ill effects on the skin or general condition of the animals.

Most of the leading manufacturers have at their command chemical staffs which are working toward the perfection of their products. All are alert to any new developments which may come from the agricultural experiment stations or other sources. The research work published has varied from rather simple, poorly controlled trials to carefully planned fundamental research. Although the controlled laboratory tests have been of unestimable value, perhaps too little of the research has been done under carefully planned field conditions.

REVIEW OF LITERATURE

As early as 1889, Smith (27) reported on experiments designed to measure the efficacy of fly repellents. Graybill (13) in 1914 reviewed the literature on this subject up to that time. Although most of the reports consisted primarily of suggested formulae for fly repellents, a few included observations on repellent effect and effect on the animals. In the same publication Graybill reported on the efficacy of various combinations of several constituents. Although many of the materials which he used and also the large quantities applied per animal are not in agreement with present day knowledge, the results undoubtedly contributed to the improvement of modern fly sprays. Since then Cory (5) in 1917 reported on the use of pine tar creosote in an emulsion of water and caustic soda. In 1928 Cory (6) compared emulsions of pine oil of different concentrations with pine oil emulsion fortified with a pyrethrum-oil spray. He found the pine oil emulsions relatively ineffective as repellents, but that they appeared to have special value as a vehicle to carry more toxic materials. Baer (1) in 1926 commented briefly on a comparison of two commercial fly sprays as repellent for dairy cows. Cleveland (4) also in 1926 reported on a comparison of several sprays, but results were based on casual observations when used by dairymen. In 1933, Pearson, Wilson and Richardson (20) concluded that staking cows individually and making hourly fly counts was more satisfactory than gross observations on larger numbers of cows under typical herd conditions. A complete review of techniques in testing fly sprays was reported by Nelson (19) in 1941 as chairman of the committee on cattle sprays of the National Association of Insecticide Manufacturers. The committee reported the need for field tests but did not approve of any field method. More papers have been published on refinement of techniques in recent years than on measurement of repellency of different materials.

In fact, the paucity of published data during recent years on the relative repellence of known materials is rather surprising. Fitch and Lush (8, 9) in 1926 and 1928 compared four commercial sprays and a home made spray during the fly season of 1924, and two commercial sprays during 1925. They concluded that all sprays were effective and about equal for the first 1½ hours after spraying. Eight hours after spraying the sprayed animals had fewer flies on them than those not sprayed. Later Freeborn and Regan (12) in 1932 reported on the repellent effect of mixtures of known quantities of pyrethrum or pyrethrum and pine oil in oils of known viscosity and unsulphonated residue content. They concluded that pine oil added to the effectiveness of the pyrethrum-oil mixtures, and that the heavier bodied oils were superior, but that oils containing sulphonated residues or unsaturates might be injurious to cows. Pearson's (21) 1935 experiments represent the most extensive carefully controlled work which has been directed primarily toward measurement of repellency of materials of known composition. He used a uniform base oil with and without various quantities of pine oil, pyrethrum, derris, aliphatic thiocyanate, and combinations thereof. He concluded that pine oil increased the repellency of pyrethrum extract or of derris, and that pine oil did not affect the repellent effect of aliphatic thiocyanate.

EXPERIMENTAL METHODS

Field experiments on the efficacy of various fly spray constituents, combinations thereof, and some commercial sprays were conducted. Since different procedures were used, the procedure involved will be described previous to discussion of results of each series of trials.

Sixteen cows were used in each of the first two trials. The relative fly susceptibility of each cow was determined by a preliminary trial of four days. Then, the cows were divided into groups of four cows, the group being balanced according to fly susceptibility. The groups were numbered 1, 2, 3, and 4. During the first four days Group 1 was unsprayed and acted as a check while Groups 2, 3, and 4 were sprayed with selected materials, thereby making possible comparison of three sprays with check. At the end of each four-day period, the groups were rotated in numerical order, Group 2 becoming the check group, Group 4 being sprayed with that previously used on Group 3, and Group 1 taking the previous place of Group 4. At the conclusion of the second four-day period, the groups were shifted again in numberical order, and the same was done on the fourth four-day period. Under this "round robin" system covering 16 days, all 16 cows were used as checks for a four-day period, and likewise were sprayed for four days with each of the three sprays being studied.

Spraying of the animals was begun at 6:00 a.m. and fly counting was begun at 7:00 a.m. Hourly fly counts were made until 3:00 p.m. when the cows were brought in to be milked. The cows were always sprayed and counted in the same order. Spray was applied as uniformly as possible over the entire body with a small electric sprayer, using 25 cc of spray per cow in the first two series and 30 cc in the last two series. The cows were washed at the conclusion of each four-day period, before being used either as a check group or for study of a different spray material. The cows were staked individually in the same pasture without shade while being observed for fly numbers.

When the data obtained were studied, it became apparent that within sprays, within groups of cows, or within hours, the distributions of fly numbers were quite definitely skewed. While the majority of the counts per cow per hour fell below 25, enough of the counts were greater than 25 with some ranging on up into the hundreds to make the arithmetic mean a misleading measure of the typical count for a given classification. Moreover, proper measures of variability could not be obtained.

It was found that the sampling mean, $\bar{x}$, and the sampling variance, V, were significantly correlated for any particular classification, indicating a serious amount of non-normality. Plotting, and the value of the correlation coefficient, r, showed the relation between $\bar{x}$ and V to be chiefly linear when three sprays and a check were used; so a square root transformation was used.

Since most of the counts were below 50, 0.5 was added to each count before the square root was taken. When six sprays and a check were used, the situation was different. There was a higher linear correlation, r, but the relationship between $\bar{x}$ and V could be seen to be poorly represented by a straight line. Moreover, it was found that after the square root transformation had been applied, the correlation between $\bar{x}$ and V was still essentially as high as it was before. Therefore the reciprocal square root transformation, $y = \frac{1}{\sqrt{\text{Flies} + 10}}$, will remove the correlation between $\bar{x}$ and V and will produce satisfacotry normality. The transformations justified themselves in this study by reducing the linear correlation, r, from highly significant values to definitely non-significant values in all cases investigated. That the transformations had done much to remove excessive non-normality was shown graphically also by the distributions in the transformed data. All analyses and comparisons of means are based on the transformed data.

Although the initial series were conducted in a systematic manner, all essentially followed Latin square designs. Groups of cows, periods of time, and sprays were taken as the rows, columns, and treatments within cells respectively. The 7x7 Latin squares used in the last half of the tests were non-systematic.

The data obtained in the tests described above were analyzed by means of the Analysis of Variance, and t-tests. The data were arranged in two ways in order to obtain more information: (1) in a spray x hour classification; and (2) in a Latin square arrangement on groups, periods, and sprays. The former grouping showed the way in which the effects of the sprays diminished during the day and gave an opportunity to describe that trend statistically. The latter grouping - used only on the 7x7 squares - gave the proper error term for spray comparisons.

Accuracy of original data is of fundamental importance. Since flies move about while the count on an individual cow is in progress, and since the fly numbers vary widely between cows and hourly counts, the accuracy of the counting might be questioned. Comparison of counts obtained simultaneously on the same cows by two operators showed no significant differences, when statistically analyzed. Likewise, an analysis of the relative constancy of fly susceptibility of individual cows, and the accuracy of balancing groups according to fly susceptibility showed no significant differences between groups.

Since the results showed that horn flies are easily repelled by any of the sprays tested, the data on stable flies only will be presented to avoid confusion, save time, and show differences between spray materials.

RESULTS

Series I and II were conducted by systematic rotation.

Series I

The first series consisted of a comparison of check, 3 percent Thanite in base oil, 2½ percent of a 20:1 concentration of pyrethrum plus 15 percent Yarmor pine oil in base oil, and 3 3/4 percent of a 20:1 concentration of pyrethrum plus 10 percent Yarmor pine oil (Table 1).

All three sprays were highly effective as measured by statistical differences between the "over-all" means of the transformed data when compared with check (Table 1). The most effective spray was the pyrethrum mixture composed of 3 3/4 percent of 20:1 concentrate of pyrethrum plus 10 percent of Yarmor pine oil. The other pyrethrum mixture (2½ percent pyrethrum concentrate 20:1 plus 15 percent Yarmor pine oil) was second. Thanite (three percent) in base

Table 1. The "over-all" and hourly repellency of 3 percent Thanite, in base oil, 2½ percent of 20:1 concentrate of pyrethrum plus 15 percent Yarmor pine oil, in base oil, 3 3/4 percent of 20:1 concentrate of pyrethrum plus 10 percent Yarmor pine oil, in base oil (Transformed data)

Sprays used	Over all mean*	Difference from check	Hourly means 7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 noon	1 p.m.	2 p.m.	3 p.m.
Check - no spray	6.51		5.62	6.83	7.67	7.30	6.60	6.10	5.96	5.97	6.57
Thanite, 3 percent in base oil	4.03	2.48	2.04	2.83	4.30	4.36	4.27	3.96	4.31	5.01	5.24
Pyrethrum, 2½ percent of 20:1 conc. plus 15 percent Yarmor pine oil, in base oil	3.62	2.89	1.84	2.51	3.50	4.07	3.68	3.31	3.33	3.96	4.97
Pyrethrum, 3 3/4 percent of 20:1 conc. plus 10 percent Yarmor pine oil, in base oil	3.31	3.20	1.94	2.28	3.23	3.67	3.76	3.18	3.63	3.74	4.38

*Mean - mean of the squar roots of individual fly counts plus 0.5

Note - Base oil used was colorless, odorless distillate with a viscosity of 36 - 41 seconds.

Significant difference	Over all	hourly
Minimal significant difference (odds 1-19)	0.60	0.73
Highly significant difference (odds 1-99)	0.68	0.95

oil ranked third. The difference between the "over-all" means of the two pyrethrum mixtures was not significant. The difference in favor of the 2½ percent pyrethrum mixture when compared with the Thanite mixture was barely of minimal significance. The 3 3/4 percent pyrethrum mixture, however, showed a highly significant difference from the Thanite mixture.

Study of the hourly means shows that the effectiveness of each of the sprays diminished as time from spraying increased. Much higher repellence was obtained during the first and second (1½ hours) fly counts than on later hourly counts. Much of the difference in "over-all" means is due to the first two counts because after the third hourly fly count (2½ hours) until the seventh count (6½ hours) the three sprays remained about the same in effectiveness. On the ninth hourly fly count the differences between check and each of the sprays were still highly significant. These facts lend encouragement to the hope of developing fly sprays that will be effective from one milking until another, but they also raise the question of how completely cows can be protected from flies by spraying.

Series II

Series II consisted of a comparison of check, five percent "D.H.S." activator in base oil, 2½ percent of 20:1 concentration of pyrethrum plus five percent "D.H.S." activator in base oil, and three percent Thanite in base oil (Table 2). The purpose of these comparisons were to determine whether "D.H.S." activator alone had any effect on repellence, and whether the pyrethrum mixture when fortified with five percent of the activator would be more effective than a three percent Thanite base oil mixture.

Study of the "over-all" means shows that the "D.H.S." activator in base oil was no more effective than the unsprayed group. This is further

Table 2. The "over-all" and hourly repellency of 5 percent D.H.S. activator, in base oil. $2\frac{1}{2}$ percent of 20:1 concentrate of pyrethrum, in base oil, and 5 percent Thanite in base oil. (Transformed data)

Spray used	Over all mean*	Difference from check	Hourly means*								
			7 a.m.	8 a.m.	9 a.m.	10 a.m.	11 a.m.	12 noon	1 p.m.	2 p.m.	3 p.m.
Check - no spray	6.71		5.54	6.04	6.54	7.26	7.16	6.62	6.96	7.37	6.87
D.H.S. activator 5 percent in base oil	6.73	0.02	5.09	5.85	6.72	7.77	7.34	6.50	7.16	6.91	7.16
Pyrethrum, $2\frac{1}{2}$ percent of 20:1 conc. plus 5 percent D.H.S. activator, in base oil	5.92	0.79	3.26	4.33	5.95	6.15	6.16	6.22	6.84	6.80	7.08
Thanite, 5 percent in base oil	5.79	0.92	3.56	4.33	5.42	5.93	6.64	6.05	6.60	6.53	7.05

*Mean = mean of the square roots of individual fly counts plus 0.5

Note - Base oil used was colorless, odorless distillate with a viscosity of 36 - 41 seconds.

Significant Difference

	Over-all	Hourly
Minimal significant difference (odd 1-19)	0.40	0.86
Highly significant difference (odd 1-99)	0.50	1.15

emphasized in the data on hourly fly counts. The difference between "over-all" means of the pyrethrum mixture plus "D.H.S." activator and the "over-all" means of the check group was highly significant. The difference between the Thanite mixture and check was also highly significant. The difference of the "over-all" means between the Thanite mixture and the pyrethrum mixture was not significant. In a study of the pyrethrum mixture, the data did not show a significant difference from check beyond the second count (1½ hours), while the results on the Thanite mixture showed significant repellence until the fourth fly count (3½ hours). In this series the repellent effect of the sprays lasted less than half as long as in the previous series.

In series III and IV the same general procedure was used but a randomized Latin square design replaced the systematic squares previously used. Seven groups were used and each group contained three cows instead of four as in a previous series. The procedure also differed from previous series in that 30 cc of spray was used instead of 25 cc.

Series III

The following comparisions were made:

1. 5 percent Thanite in base oil.
2. 3 percent Thanite in base oil.
3. 5 percent of 20:1 concentrate of pyrethrum, in base oil.
4. ,2½ percent of 20:1 concentrate of pyrethrum plus 15 percent Yarmor pine oil in base oil.
5. 2½ percent of 20:1 concentrate of pyrethrum plus 5 percent D.H.S. activator in base oil.
6. 2½ percent of 20:1 concentrate of pyrethrum in base oil.
7. Check (no spray).

This series represents an effort to bring together in one trial most of the combinations of spray materials previously studied. Comparison of the "over-all" means shows highly significant differences between check and each of the spray materials studied. The results are shown as transformed data in Table 8. When the mixture of 2½ percent of 20:1 concentrate pyrethrum in base oil is compared with the same mixture plus five percent "D.H.S." activator the "over-all" mean is found to be a little greater for the mixture

Table 8. Ordered "over-all" spray means and least significant differences from data transformed by the reciprocal square root transformation. All sprays were in base oil.

Spray	Mean
1. 5 percent Thanite in base oil	0.222
2. 3 percent Thanite in base oil	0.218
3. 5 percent pyrethrum	0.210
4. 2½ percent pyrethrum plus 15 percent Yarmor Pine oil	0.204
5. 2½ percent pyrethrum plus 5 percent D.H.S. activator	0.201
6. 2½ percent pyrethrum	0.200
7. Check (no spray)	0.139
Minimal significant difference	0.009
Highly significant difference	0.012
Very highly significant difference	0.015

containing the activator but the difference is not sifnificant. Likewise it was found that the addition of 15 percent "Yarmor" pine oil to the original pyrethrum mixture did not result in a significant difference. Although the mixture containing "Yarmor" pine oil showed a greater average difference from check than either of the other pyrethrum mixtures, this difference is well within the limits of experimental error.

The difference between the "over-all" means for 2½ percent pyrethrum in base oil and the same mixture containing five percent pyrethrum was of minimal significance, indicating that the additional pyrethrum increased the effectiveness of the spray. Whether the increased effectiveness is enough to justify doubling the amount of pyrethrum used is a question.

The results obtained with the mixture of three percent Thanite in base oil were better than the results obtained with any of the previously mentioned sprays in this series. The "over-all" difference between this mixture and the mixture containing five percent of a 20: 1 concentrate of pyrethrum was just short of significant. The three percent Thanite mixture was superior to any of the other spray mixtures previously mentioned as indicated by highly significant differences between the "over-all" means.

The mixture containing five percent Thanite produced the lowest "over-all" mean fly-count when compared with any of the other five spray mixtures. In fact, differences were highly significant compared with all other sprays, except the three percent Thanite mixture. The difference between the three percent and five percent Thanite mixtures was non-significant.

Study of the hourly means shows the same relative results for the sprays used as did the "over-all" means (Table 4). All of the sprays showed highly significant differences from check at the eight hourly fly-count ($7\frac{1}{2}$ hours after spraying). This indicates longer effect than is commonly believed.

The sprays did not differ greatly in the hold-over effect from hour to hour. (There does seem to be a minimal significant "over-all" effect caused by the addition of "D.H.S." activator to the pyrethrum mixture.) The same is true for the addition of "Yarmor" pine oil. The Thanite mixtures had more hold-over effect than any of the other sprays.

Table 4. Hourly spray means for the data in series three transformed by the reciprocal square root transformation with significant differences between spray and hour indicated.

Spray	Hour 7	8	9	10	11	12	1	2
5 percent Thanite	.276	.260	.238	.218	.215	.212	.184	.176
3 percent Thanite	.276	.253	.231	.204	.209	.209	.188	.177
5 percent pyrethrum	.274	.247	.222	.196	.201	.198	.178	.168
2½ percent pyrethrum	.267	.234	.208	.184	.183	.184	.176	.164
2½ percent pyrethrum plus 10 percent pine oil	.266	.234	.213	.188	.191	.190	.177	.175
2½ percent pyrethrum plus 5 percent D.H.S. activator	.260	.235	.206	.190	.189	.187	.176	.166
Check	.153	.132	.133	.128	.137	.147	.142	.156

Minimal significant difference (odds 1:19) 0.018
Highly significant difference (odds 1:99) 0.024
Very highly significant difference (odds 1:999) 0.031

Series IV

Series IV represented a comparison of several commercial sprays with a recommended home-made spray, and with three percent Thanite in base oil. The object of this series was to evaluate the Thanite mixture, which had proved more satisfactory than most other mixtures, in terms of some accepted sprays. In other words, how good is a good spray? The supply of each commercial spray was purchased on the open market in sealed cans. The comparisons made were as follows:

Thanite three percent, in base oil
U. S. Dept. Agri. spray, in fish oil
Spray No. 4
Spray No. 3
Spray No. 2
Spray No. 1
Check - no spray

The "over-all" mean of each of the sprays studied in this series showed a highly significant difference when compared with the check group (Table 5).

Table 5. Ordered "over-all" spray means and least significant differences of four commercial sprays compared with two sprays of known composition.

Spray	Mean
Thanite 5 percent, in base oil	0.225
U. S. Dept. Agr., in fish oil	0.220
Spray No. 4	0.215
Spray No. 3	0.212
Spray No. 2	0.209
Spray No. 1	0.206
Check - no spray	0.169

Minimal significant difference	(odds 1:19)	0.009
Highly significant difference	(odds 1:99)	0.012
Very highly significant difference	(odds 1:999)	0.016

Statistical analysis showed that spray No. 1 is significantly poorer as a repellant than No. 4 or the U. S. Department of Agriculture spray. That the U. S. Department of Agriculture spray is a better repellant than spray No. 2 is also not open to reasonable doubt. The Thanite mixture was the most effective of the sprays tested. The difference between it and the home-make spray was not significant, while the difference between it and the best commercial spray was of minimal significance and highly significant compared with the other commercial sprays.

Certain outstanding differences are noticeable in the hold-over effect of the different sprays (Table 6). Only two of the sprays differed from check significantly at the sixth hourly fly-count. At the eighth hourly count, only one commercial spray among all the sprays was just barely significantly different from check. However, at the seventh hourly count, Thanite was still significantly better than check and was as repellant as any of the sprays tested.

Table 6. Hourly spray means for the data in series four transformed with significant differences between hour and spray indicated.

Spray	Hour 7	8	9	10	11	12	1	2
3 percent Thanite	.287	.267	.247	.218	.203	.204	.194	.178
U. S. Dept. of Agr.	.287	.255	.234	.209	.197	.197	.194	.186
Spray No. 4	.279	.249	.227	.201	.193	.194	.194	.181
Spray No. 3	.265	.243	.216	.203	.196	.194	.188	.188
Spray No. 2	.260	.246	.214	.196	.186	.190	.183	.177
Spray No. 1	.271	.235	.205	.193	.189	.191	.182	.180
Check - no spray	.187	.169	.168	.160	.167	.172	.166	.163

Minimal significant difference (odds 1:19) 0.024
Highly significant difference (odds 1:99) 0.032
Very highly significant difference (odds 1:999) 0.041

Three percent Thanite in base oil was superior to fly spray of known ingredients and to four commercial sprays tested for repelling stable flies.

PART II. SOME INVESTIGATIONS OF FLY CONTROL IN DAIRY BARNS

PRESENTATION OF THE PROBLEM

Flies are such a serious pest to livestock that most stockmen make some effort to control them. On dairy farms, the problem is especially important due to the danger of contaminating milk. The United States Public Health Service (29) has recognized the problem by prescribing regulations for approved dairy farms where Grade A milk is produced. Fenton and Bieberdorf (7) and Searls and Snyder (25) recommended two general methods of control: 1. elimination of breeding places, and 2. systematic killing of large numbers of flies. Frequent removal of manure by spreading it on field, elimination of stack bottoms, damp piles of feed or waste material together with utmost cleanliness inside the barn will greatly reduce the numbers of flies if a systematic program is followed on most farms indicates that more emphasis is placed on killing methods rather than the prevention of breeding. Killing methods include such recommendations as poison bait, traps, electric screens, spraying, or a combination of two or more such methods. Feeding drugs to cows to prevent flies from breeding in the droppings has even been tried by Bruce (3) Graybill (13) and Kipling (16). Fans or water sprays on doors and other devices have been used to keep flies out of stables. Sprays either of the killing or repellent type, or both, are probably more universally used than any of the other systems of reducing fly numbers. Under practical conditions, fly control is a serious problem even when the approved methods are systematically followed. Each method has advantages and disadvantages. In this investigation an attempt was made to measure the effectiveness of a combination of various methods of fly control in dairy barns. The investigations were conducted in the dairy barn at the Kansas Agricultural Experiment Station. This barn is a large modern structure, well situated, in which Grade A milk is produced. The milking barn floors and side walls are washed after each milking period. Walls are constructed of glazed tile and the ceiling is plaster coated with enamel paint. Breeding places for flies were eliminated under the supervision of staff members of the Department of Entomology. The sanitation program was followed to the extreme of picking up scattered droppings in the lots twice weekly. Since fly numbers were still a problem under these rather ideal farm conditions, the need for measuring the effectiveness of several control methods and various combinations of methods were indicated.

SCREENS COMPARED WITH NO SCREENS

The Standard Milk Ordinance Code of the United States Public Health Service (30) prescribes screens on the milk house windows but does not require them on the barn. Even among the better equipped dairies, the question of screens on barns is controversial according to Bishop (2) and Hordsman Corner (14). Some dairymen maintain that when the doors are opened and the cows are brought in, a large number of flies follow the cows, and the screens act as a trap to hold the flies in the barn. Others list screening of the barn as one of the first steps in controlling fly numbers in the barn.

In these investigations comparisons of screens and no screens were made in the maternity barn, calf barn, and nutrition barn. These barns were separate sections of the same building. Each of the barns was bedded with straw, changed daily. All the data were collected during August and September. Flies were counted many times on selected areas of the ceiling and wall when the screens were off and again when on for several days. No spraying was done in the barns during the periods when data were taken. Average numbers of flies were compared on the same areas with the screens off and on (Table 7).

On the areas of ceiling and walls selected for fly counting, there were 21 flies per 100 square feet of surface in the nutrition barn when the screens were off, and five flies on the same areas when the screens were on. In the calf barn the flies counted were 26 with the screens off and six when the screens were on. Counts in the maternity barn showed 16 flies with screens off and two with screens on. The number of flies were also counted on three selected calves in the calf barn. When screens were off the average number of flies per calf was 31, and eight on the same calves when screens were on. In

Table 7. Fly counts in three dairy barns with and without screens during August, 1941; (A) nutrition barn (B) calf barn (C) maternity barn.

Barns studied	Screens off: No. of fly counts	Screens off: Avg. no. flies per 100 sq. ft.	Screens off: Flies on animals: No. animals	Screens off: Flies on animals: Avg. No. flies	Screens on: No. of fly counts	Screens on: Avg. no. flies per 100 sq. ft.	Screens on: Flies on animals: No. animals	Screens on: Flies on animals: Avg. no. flies
A	24	21			10	5		
B	27	26	5	31	33	6	3	8
C	31	16	2	66	20	2	2	28

the maternity barn two mostly white Ayrshire cows were selected for fly counts. When the screens were off the average number of flies per cow was 66, and 28 per cow when screens were on.

Although selected areas of known size could not be used to estimate the number of flies in the entire barn, nevertheless the counts with screens off and on should measure relatively the effectiveness of screening barns as a supplementary method of controlling fly numbers in a dairy barn. Considering the fact that different days were involved, the data obtained in the three barns show substantially the same results. When the screens were off approximately four times as many flies were counted as when the screens were on. These results would indicate that screens are measurably effective even when cattle are turned in an out of the barn.

No spraying was done in the barns during the period of study but it is well to emphasize that this study was coupled with a systematic manure disposal program throughout the season and the barn had been sprayed daily with a killing spray previous to the period of study.

FLIES BROUGHT INTO THE BARN WITH CATTLE

When cattle are turned in and out of a screened barn, flies can come in through the open doors or be brought in on the cattle. An attempt was made to measure the increase in numbers of flies caused by bringing in the cattle (Table 8). The numbers of flies were measured by counts on selected areas of walls and ceiling. In the milking barn, the floors of which were washed, the increase in fly numbers was not important. However, in the calf barn, which was bedded, the fly numbers were greatly increased after the cattle were brought in, possibly due to the odor of the bedding. Only one daily trial was conducted on each barn and each barn was comparatively free from flies before the cattle were brought in. The cumulative effect over a longer period in a screened barn might be different. In clean barns when spraying is regularly practiced to keep down fly numbers in addition to screening to keep out flies, it may be concluded that the necessary opening of doors to bring in the cattle does not defeat the value of screens by trapping flies in the barn.

Table 8. Increase in fly numbers in barns when cattle are brought in milking barn August 19 and on calf barn August 8.

Cattle in or out	No. of fly counts*	Avg. no. flies per 100 sq. ft.
Milking barn with screens on		
Cows out	6	4
About ½ the cows brought in	8	11
Two hours later other cows brought in	3	15
Calf barn with screens off		
Calves out	3	36
Calves brought in	6	186

* Approximately 45 minute intervals.

EFFECTIVENESS OF SPRAYING WITH AND WITHOUT SCREENS

Many dairymen spray their barns to reduce the number of flies. The effectiveness of spraying barns with and without screens was compared with no screens or no spraying (Table 9). The results were measured by fly counts on selected areas of the walls and ceiling. Cattle were kept in both barns and the box stalls were bedded with straw, the stalls being cleaned each morning in the usual manner. Use of the barns in this way offered a better opportunity to attract flies than if the barns had been empty and free from litter.

Table 9. Combination of spraying barns with and without screens as fly control measures as observed during August 1941, which cattle in barn during observations.

Screens on or off	Sprayed or not sprayed	No. of fly counts	Avg. no. flies per 100 square feet
	Maternity barn		
on	No	1	59
taken off	No	1	58
off	Barn sprayed	4	65
off	No	1	68
off	Barn sprayed	11	67
on	Barn sprayed	12	2
on	No	6	21
taken off	No	10	43
	Calf barn		
on	Barn sprayed	4	30
on	Barn sprayed	5	21
on	Barn sprayed	6	0.4
on	Barn sprayed	1	0
taken off	No additional spraying	9	51

Although spraying the barn killed large numbers of flies, there was no advantage in spraying as a means of reducing the average number of flies in the barn unless the barn was screened. Counts a short time after spraying without screens were smaller but the advantage was soon lost due to the flies coming into the barn. These results indicate that spraying alone is of doubtful value as a control measure. A combination of screens and spraying resulted in quite effective control of fly numbers in the barns over several hours. Such a combination would eliminate any trapping effect caused by screens when cattle are brought in or out. These findings are of interest as a supplement to the data in Table 7, which showed that screens alone were much more effective as a control measure than no screens.

THE VALUE OF SCREENS

It is well known that flies in the barn migrate to the light of the windows. This fact has caused some dairymen to question the efficiency of screens and has also caused them to raise the question of the trapping effect of screens. To answer this, fly counts were made on the inside of the window screens and on wall areas of similar size adjoining the screens. In the milking barn while the cows were out, the average number of flies per 100 square feet was 236 on the inside of the screens and 25 on the walls adjoining (Table 10). In the calf barn with the calves in, there were 370 flies per 100 square feet on the screens and 70 on the walls. When counts on the outside of the screen, there were found to be 230 on the inside and 10 on the outside of the screens on the milking barn, and 370 on the inside and 50 on the outside of the calf barn screens.

Table 10. Comparison of numbers of flies on screens and walls of two barns (A) milking barn, (B) calf barn on August 6 and 9, 1941.

No. of fly counts	Screens counted	Cattle in or out	Avg. no. of flies per 100 sq. ft.	
			on inside of window screens	on walls adjoining windows
20 in A	8	cows out	286	25
13 in B	5	calves out	370	79
			on inside of screens	on outside of screens
34 in A	8		230	10
13 in B	5		370	50

These findings are especially significant because they were obtained in a barn particularly well lighted by windows. These results lend credence to the claim that flies migrate to the light. They also suggest the probable effectiveness of traps in windows, such as the Hodge fly trap, or electric screens on some of the windows as a supplement to the value of screens. The practice of darkening some or all of the windows to keep house flies out of a barn is also supported by these findings, although such a method may be criticised from the viewpoint of clean milk production because of insufficient light in the barn.

EFFECT OF CLEANLINESS OF FLOORS AND MANGERS ON FLY NUMBERS

Barn floors are usually cleaned by sweeping only, sweeping and liming, or washing. An attempt was made to measure the relative effectiveness of each cleaning method by counting the flies on the floors (Table 11).

One side of the nutrition barn was in use while the other side was not used. On the side in use the floors were bedded and kept rather dirty. The floors of the unused side had been scrubbed. When the screens were off and

Table 11. Average number of flies for two to four days each on ceiling, walls or floors of three barns (A) nutrition barn (B) experimental barn (C) milking barn during August, 1941, illustrating barn cleanliness as a factor in fly numbers.

Barns	Location of area counted	Screens on or off	Animals in or out	Comparisons: Avg. no. of flies per 100 sq. ft. and condition of floor		Comparisons: Avg. no. of flies per 100 sq. ft. and condition of floor	
(A)	Ceiling and walls	off	in	125	uncleaned	16	cleaned
(A)	Ceiling and walls	on	out	8	uncleaned	0.4	cleaned
(B)	Floor	on	in and out	76	Swept only	27	freshly limed
(B)	Floor	on	in and out	48	day old lime	8	freshly limed
(C)	Feed alley	on	in and out	9	swept only	0.1	scrubbed
(C)	Manger	on	in and out	282	swept only	18	scrubbed

the cattle kept in the barn, the number of flies per 100 square feet on selected areas of ceiling and walls was 125, while the number of flies on similar areas on the clean side was only 16. Fly counts in the same barn with the cows out and the barn screened showed an average of eight flies on the dirty side of the barn and four-tenths of a fly on the clean side. The barn had been sprayed previous to this second series of tests. These results indicate the importance of cleanliness of floors and the olfactory response of flies as stated by Hoskins and Craig (16).

Effectiveness of liming floors was studied in the experimental barn with screens on and the cattle turned in and out of the barn. Numbers of flies on the floor were used as a measure of results. On the section of floor swept only, there were an average of 76 flies per 100 square feet; while on the section of floor freshly limed daily there were 27 flies. The difference might have been greater had there not been some residual lime from previous liming of the unlimed section of floor. When fresh limed floors were compared with day-old lime, partly soiled, 48 flies were counted on the day-old limed floor and eight flies on the freshly limed. These two comparisons indicate that fresh lime on the floor acts as a repellent to flies and that flies are easily attracted by even slightly soiled floors.

Due to the fact that feed alleys are not so badly soiled as cow stalls and alleyways back of the cows, dairymen sometimes only sweep the feed alley even though they may scrub the rest of the barn floor. Comparison of sweeping with scrubbing of the feed alley was made in the milking barn, the rest of the barn being scrubbed after each milking period. The average number of flies counted on the floor was nine, when the floor was swept only, and 0.1 when the floor was scrubbed. Although the cleanliness of the floor was reflected in the number of flies counted, it is doubtful whether scrubbing the feed alley is justified, provided the floor is swept, even though silage, hay and grain are spilled in it.

Swept mangers were also compared with scrubbed mangers in the milking barn. On the section swept only, there were 282 flies per 100 square feet, while on the scrubbed sections there were 16 flies on the same area. Accumulation of feed mixed with slobber of the cows often sours in the mangers and makes them unsanitary. In these trials the practice of washing all sections of the mangers had been followed and the condition of the unwashed sections during the trial had no previous accumulations. The large numbers of flies found on the unwashed mangers compared with floors, walls and ceiling during the other trials and the small number found on the washed mangers emphasizes the importance of washing mangers to avoid attracting flies.

In all these comparisons the attraction of flies to dirty or soiled areas of the barn, depending on degree, is consistently shown.

NUMBER OF FLIES ON DIFFERENT LOCATIONS IN THE BARNS

In most of the comparisons reported in this paper the number of flies in the barn were measured by counting the number on selected areas on the walls and ceilings. The same areas were counted throughout the study. It was apparent early that more flies congregated on the sides of the beams than on other areas. Therefore, sections of the beams, both bottom and sides were included in all counts.

Recapitulation of data collected in connection with various fly control methods made possible a comparison of the numbers of flies on several areas of the barn (Table 12). The average of all counts in each barn showed that

Table 12. Number of flies in different areas of the barn in August, 1941 (A) milking barn (B) maternity barn (C) calf barn (D) nutrition barn (E) young stock barn.

Barns	No. of fly counts	Location and avg. No. flies per 100 sq. ft.				Remarks
		walls	ceiling	bottom beams	side of beams	
(A)	22	3	6	3	66	screened and scrubbed
(B)	64		23	27	113	screened and bedded*
(C)	74		39	40	132	screened and bedded*
(D)	47	46	32	52	209	screened and bedded*
(E)	74	70	114	142	1072	unscreened and bedded

* Some counts included when screens were off.

there were generally a few more flies on the ceiling and bottom of beams than there were on the walls. The sides of the beams however had many more flies than the other areas, the difference being more pronounced with larger numbers of flies present.

WALL COLOR PREFERENCE OF FLIES

Some dairymen paint the inside of the window panes with blue calcimine as a method of reducing fly numbers in the barn as suggested by Marre (13) and Herdsman Corner (14). This tends to make the barn darker and probably causes the flies to migrate to open windows or window traps. Just why blue seems to be the accepted color is unknown. An attempt was made to determine whether flies showed any significant preference in wall color or perhaps put in the reverse order whether certain colors tended to repel flies more than others. A ply board panel four feet high and six feet wide was painted in three square foot areas with seven different colors of paint and one area left unpainted. The chart was hung lengthwise about head height on the wall of an unscreened barn. Trials of two different color combinations were conducted, 132 counts being made in the first trial and 181 in the second (Table 13).

The fly counts were made between August 6 and September 24. The data were analyzed by the analysis of variance. It was necessary to obtain the square root transformation ($y = \sqrt{x + 0.5}$) prior to the analysis since the counts were found to be distributed in a Poisson-like manner as described by Snedecor (28).

Table 13. Color preference of flies determined by numbers of flies on square foot areas of a wall board hung in the dairy barn.

Trial 1 - 132 counts		Trial 11 - 181 counts	
Color	Avg. no. flies per 100 square ft.	Color	Avg. no. flies per 100 square ft.
Silver Gray	69	Orchid	75
White	76	White	106
Baby Pink	81	Unpainted wood	112
Celestial Blue	104	Blue	119
Royal Carmine	140	Brown	139
Unpainted wood	153	Green	150
Lettuce Green	161	Yellow	163
Cream	162	Black	191

Although differences existed in the average numbers of flies counted on the various color squares, statistical analysis showed that during the first trial the differences between the first three colors (silver gray, white and baby pink) were non-significant. Neither were the next five colors celestial blue, Royal carmine, unpainted board, lettuce green and cream significantly different from each other. The difference between the latter five and the former three colors was significant (odds of 1:19 that results were due to chance), and the difference between some of the extremes of the two groups was highly significant (odds 1:99 that the results were due to chance).

The reaction of the flies to the various colors during the second trial showed more significant differences. When analysed statistically the difference between the colors in the order listed were all highly significant with the exception of white and unpainted which were non-significant, and the same for brown and green. Again, in this trial the numbers of flies on the different colors fell into two groups, the first four lighter colors having considerably fewer flies than the four darker colors.

These results are in reasonable agreement with conclusions of Lee (17) who measured the color responses of blow flies (Lucilia cuprina) by the number caught in glass traps colored by different colors of cellophane. He found yellow to be the most attractice color, with blue, pink and green ranking in the order named, but the differences in the last three appeared to be of doubtful significance.

Freeborn and Berry (11) counted the fly specks accumulated on different colored squares of a dairy barn ceiling. They found graduations in numbers from light to dark with little difference among the light colors. Their results are similar to those reported in this paper except for the color carmine in the first trial.

The principal finding from these comparisons is the fact that the flies seemed to prefer the darker colors when the panel was hung in a well lighted barn. Since dairy barns are generally painted light colors for sanitary reasons, it is doubtful whether color preference of flies is important in the selection of wall colors for dairy barns.

RELATIVE EFFICIENCY OF SOME SPRAYS IN "KNOCKDOWN" AND "KILL"

Since barn spraying is extensively used as a method of controlling fly numbers, the variation in efficiency of sprays is of interest to the dairymen. Two general types of sprays are on the market, the repellent type and the killing type. Dairymen would prefer to have a spray that would fulfill both functions. Two sprays might differ in repellance but rank in opposite order in killing power. Observations indicate that sprays differ considerably in comparison of knockdown and kill. Several sprays of known composition, which had previously been tested for repellance, were tested for knockdown and kill.

Three nationally advertised livestock sprays were also selected for comparison (Table 14).

The procedure used consisted of hanging cylindrical screen wire cages (about six x nine inches) with screen wire tops and bottoms in two barns containing cattle. The cages were hung 12 feet from the center of the barn and about 1½ feet from the wall. Four cages were equally spaced throughout the barn. A known number of flies (from 50 to 100) were placed in the cages; and the barn was sprayed with a power sprayer to get a good dispersion. The volume of each barn was about 11,500 cubic feet and 300 cc (about 1/3 pint) of each spray was used, or about 1 cc for each 36 cubic feet. Ten minutes after spraying a large number of flies were gathered off the floor and a known number placed in cages containing water and sugar for feed. These cages were then taken to another building where no spraying had been done, and at the end of 24 hours the percentage of dead flies were recorded.

All data were transformed by the arc sine transformation as shown by Snedecor (28) to obtain the relative effect of the different sprays used.

Practically the same efficacy was obtained in knockdown at the end of five minutes as at the end of 10 minutes, which is in agreement with Ford (10). The number of flies which would be knocked down through longer exposure was not determined. Spray No. 1, a mixture of five percent of a 20:1 concentrate of pyrethrum in base oil (36 - 41 seconds, Saybolt viscosity) was the least satisfactory from the standpoint of knockdown. When the data were treated statistically the other seven sprays were not found to be significantly different in knockdown efficiency.

More difference in killing power was found between the different sprays used. Five of the sprays, Nos. 5, 2, 4, 7 and 1, were significantly better

Table 14. Comparison of several sprays in effectiveness of knockdown and kill. (Maternity barn and calf barn)

No.	Sprays used composition	No. of trials	Average per cent flies "down" in 5 minutes***	Average per cent flies "down" in 10 minutes	Average percent flies knocked down which were dead after 24 hours
1	Pyrethrum, 5 percent of 20:1 conc. in base oil*	10	26****	31	86
2	Pyrethrum, 3 3/4 percent of 20:1 conc. plus 5 percent D.H.S. activator** in base oil	12	57	72	94
3	Commercial spray No. 1	9	61	63	66
4	Thanite, 5 percent in base oil	8	68	85	92
5	Pyrethrum, 2½ percent of 20:1 conc. plus 5 percent D.H.S., activator in base oil	14	69	78	96
6	Commercial spray No. 2	20	71	73	47
7	Thanite, 3 percent in base oil*	14	78	86	91
8	Commercial spray No. 3	8	95	94	56

* "Stanco" base oil, 36 - 41 seconds Saybolt Viscosity

** D.H.S. Activator - Ethylene Glycol Ether of Pinene. (Registered U.S. Patent Off. by Hercules Powder Company.)

*** Average of arc sine of percentage of flies knocked down, Snedecor (28)

**** The low knockdown is due to the flies being confined in a cage covered with a too finely meshed screen.

than three others, Nos. 3, 8 and 6. Some of the best sprays from the standpoint of knockdown were among the poorest as killers. For example, spray No. 8 which resulted in the best knockdown ranked next to last in killing effect. It is well to consider that the "killing" represents the relative number of flies killed among those knocked down. Therefore, a spray which showed effective killing power but poor knockdown effect would be inefficient in killing all the flies in a barn. The variation between sprays in knockdown and kill, and the relative efficiency of some sprays in both, indicates the importance of considering both factors in the development of barn sprays.

OBSERVATIONS ON SPRAYING METHODS

In preliminary trials an attempt was made to simulate the Peet-Grady laboratory method (23) and Peet and Grady (22) by using the same quantity of spray material per cubic foot of volume in the barn as was used in the Peet-Grady testing chamber (1 cc of spray material per 18 cubic feet of volume). It was soon found that such a ratio of spray to volume was impracticable for barn tests, because the floors became so slippery from oil coating that it was difficult to work in the barn, and the fog of spray was more than would seem necessary.

After experimenting with various ratios of spray material to barn volume a ratio of about 1 cc of spray material to 36 cubic feet of barn area was adopted as a satisfactory standard procedure. It will be noted that this ratio represents one half the amount of spray used in the Peet-Grady laboratory testing methods (23) and that suggested earlier by Peet and Grady (22).

Some difficulty was also experienced in obtaining an apparently desirable fog condition in the barn when oils of more than 50 seconds Saybolt viscosity were used as the base for spray ingredients. The results are in agreement with the reports of Searls, and Snyder (24) and Searls (26).

OTHER PHASES OF THE STUDY

Observations on temperatures of animals as a result of spraying and changing daily environmental conditions have been recorded throughout the study. Since further work on the subject is under way and the results of the first years observations have not been fully analyzed, these data are not included in this report.

Furthermore the data on seasonal fly trends which have also been recorded during the conduct of this study are not included.

CONCLUSIONS

1. This study indicates that "Thanite" possesses considerable value as an active ingredient in fly sprays. It is therefore a possible substitute for pyrethrum as a repellent against stable flies in the field and as a toxic ingredient of fly sprays for use against house flies in the barn.
2. Skewed distribution of fly numbers on cattle necessitated transformation of the data to normality before applying the Analysis of Variance test for intrepreting differences between sprays.
3. Accuracy of counting was tested by having two operators count independently of each other at the same time. Statistical analysis showed no significant differences between the counts of the operators. Likewise, an analysis of the relative constancy of fly susceptibility of individual cows, and the accuracy of balancing groups showed no significant differences.
4. In Series I all three sprays were highly effective as a repellent against stable flies as measured by the difference of the "over-all" means compared with the check group. The three sprays ranked from best to least effective as follows: 1st. pyrethrum (3 3/4 percent 20:1 concentrate) plus 10 percent Yarmor pine oil, 2nd. pyrethrum (2½ percent 20:1 concentrate) plus 15 percent Yarmor pine oil, and 3rd. Thanite (3 percent) in base oil. The difference between the 2½ percent pyrethrum spray and the Thanite mixture was of minimal significance, while the difference between the 3 3/4 percent pyrethrum mixture and Thanite mixture was highly significant in favor of the 3 3/4 percent pyrethrum. All three sprays were of approximately equal value after the third hourly count until the seventh count.

5. Series II showed that "D.H.S." activator alone in base oil was no more effective in repelling stable flies than no spray. A misture of Pyrethrum ($2\frac{1}{2}$ percent of 20:1 concentrate) plus 5 percent "D.H.S." activator was highly significant in difference from the check group. The same was true for Thanite (three percent) in base oil. The difference between the "over-all" mean of the pyrethrum mixture and the "over-all" mean of the Thanite misture was not significant; the pyrethrum mixture was not significantly better than the check group after the first two hourly counts, while the Thanite mixture was significantly more effective for four hourly counts. The repellent effect of the sprays lasted about half as long as in the previous series.

6. In Series III an attempt was made to bring most of the previous comparisons together in one trial. All six sprays resulted in highly significant differences from the check group in repellency. Adding five percent "D.H.S." activator to a pyrethrum mixture ($2\frac{1}{2}$ percent of 20:1 concentrate in base oil) did not result in a significant different from the same mixture without the activator. Likewise, adding 15 percent Yarmor pine oil to the same Pyrethrum mixture did not cause a significant difference from the original mixture. Increasing the pyrethrum concentrate to five percent increased the effectiveness of the spray compared with a $2\frac{1}{2}$ percent mixture, but the difference was of minimal significance.

7. Thanite (three percent) in base oil was superior for repelling stable flies as indicated by highly significant differences between the "over-all" means. Increasing the Thanite to five percent increased the effectiveness of the spray but the difference was only of minimal significance. All the sprays showed highly significance differences from the check group seven and one-half hours after spraying time. Thanite had more hold-over effect than

any of the other sprays.

8. Series IV consisted of a comparison of Thanite (three percent) in base oil with four popular commercial brands of fly spray and the home made mixture recommended by the United States Department of Agriculture. The difference between Thanite and the best commercial spray was of only minimal significance.

9. Approximately one-fourth as many flies were counted in screened barns as in the same barns without screens, when systematic manure disposal and daily spraying had been in progress throughout the summer indicating the value of screens.

10. In clean barns with regular spraying the increase in numbers of flies resulting from bringing in the cows was not important; but in barns with soiled bedding, the fly numbers were greatly increased after the cattle were brought in, probably due to the odor of the bedding.

11. Spraying the barn was ineffective as a fly control measure in a bedded barn unless it was screened. A combination of screens and spraying resulted in effective control.

12. The trapping effect of screens and the tendency of flies to migrate to light were shown by the fact that nearly five times as many flies were found on the screens as on the walls in a bedded barn, while more than 11 times as many were found on the screens in a clean barn. This indicates the possible supplemental value of such control practices as darkened windows, screen traps and electric screens.

13. The importance of clean floors and the olfactory response of flies were shown by the fact that about eight times as many flies were counted on the ceiling and walls on the bedded side of a barn as were found on the clean side (floor scrubbed) of the same barn. The repellent effect of fresh lime on floors was shown by the fact that on a floor freshly limed

approximately one-third as many flies were counted as on the floor only swept in the same barn. The attraction of flies to even slightly soiled floors was shown by the fact that there were significantly larger numbers of flies on floors limed the previous day than on freshly limed floors. In a scrubbed barn the numbers of flies found on an unscrubbed (swept) feed alley and the numbers on a scrubbed feed alley did not indicate much advantage in scrubbing the feed alley. Unscrubbed mangers soiled with feed and saliva, however, had 18 times as many flies on them as were on the scrubbed mangers.

14. Numerous counts on ceilings and walls showed that Flies were found to be more numerous on the ceilings and particularly on the sides of ceiling beams than on the walls.

15. Study of color preference by flies showed that the flies preferred the darker colors. Since most dairy barns are painted in light colors for sanitary reasons, it is doubtful whether color preference of flies is important in the selection of wall colors for dairy barns.

16. Comparison of eight sprays for knockdown and kill of flies when used in a dairy barn showed that seven of the sprays were not significantly different from each other in knockdown efficiency while the eight was inferior. The three nationally advertised commercial sprays tested were significantly less efficient in killing power than were the five mixtures prepared here which were composed of various combinations of Thanite or pyrethrum concentrate. Superiority of some sprays in both knockdown and kill indicated the need for considering both factors in developing sprays for barns.

17. Satisfactory results in killing power were obtained when the amount of spray used was at the ratio of 1 cc to 36 cubic feet of barn volume which

is one-half the amount used in the Peet-Grady laboratory test; amounts simulating the ratio used in the Peet-Grady test caused the floors to become slippery. Some difficulty was experienced in dispersion of sprays made with oils of more than 50 seconds viscosity.

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LITERATURE CITED

1. Baer, A. C.
   Controlling flies that affect dairy cattle. Okla. Agr. Expt. Sta. Bienn. Rpt. 62 p. 1926.

2. Bishop, F. C.
   The stable fly: how to prevent its annoyance and its losses to livestock. U. S. Dept. of Agr. Farmers' Bul. 1097. 23 p. 1939.

3. Bruce, W. G.
   The horn fly and its control. U. S. Dept. Agr. Leaf. 205. 6 p. 1940.

4. Cleveland, C. R.
   Repellent sprays for flies attacking dairy cattle. Jour. Econ. Ent. 19(3):529-536. 1926.

5. Cory, E. N.
   The protection of dairy cattle from flies. Jour. Econ. Ent. 10(1):111-113. 1917.

6. Cory, Ernest N.
   The protection of cattle from flies. Md. Agr. Expt. Sta. Bul. 298. 19 p. 1928.

7. Fenton, F. A., and Bieberdorf, G. A.
   Fly control on A. and M. farms, Stillwater, Oklahoma. Jour. Econ. Ent. 29(5):1003-1008. 1936.

8. Fitch, J. B. and Lush, R. H.
   A study of the use of fly repellents for the control of flies on dairy cattle. Kans. Agr. Expt. Sta. Bienn. Rpt. 30:99-101. 1926.

9. Fitch, J. B. and Lush, R. H.
   A study of the use of fly repellents for dairy cattle. Kans. Agr. Expt. Sta. Bienn. Rpt. 31:95. 1926.

10. Ford, Jared H.
    Variation in Peet-Grady tests. Soap and San. Chem. 17(11):91-98,107. 1941.

11. Freeborn, Stanley B., and Berry, Lester J.
    Color preferences of the house fly, Musca Domestica L. Jour. Econ. Ent. 28(6):913-916. 1935.

12. Freeborn, Stanley B. and Regan, Wm. M.
    Fly sprays for dairy cows - A progress report. Jour. Econ. Ent. 25(2):167-174. 1932.

13. Graybill, H. W.
Repellents for protecting animals from the attacks of flies. U. S. Dept. Agr. Bur. Ent. Bul. 131. 26 p. 1914.

14. Herdsman's Corner, The. Holstein-Friesian world. 27(12):663-669. 1940.

15. Hoskins, W. M. and Craig, R.
The olfactory responses of flies in a new type of insect olfactometer. Jour. Econ. Ent. 27(5):1029. 1934.

16. Knipling, E. F.
Internal treatment of animals with phenothiazine to prevent development of horn fly larvae in manure. Jour. Econ. Ent. 31(2):315-316. 1938.

17. Lee, D. J.
A note on the colour responses of Lucilia Cuprian. Jour. Council for Scientific and Ind. Res. 10(4). Canberra, Australia. 1937.

18. Marre, Francis.
Les Mouches N'Aiment pas la Couleur Bleue. J. d' agric. prat., Paris. An. 72, n.s., t. 16, sem. 2, no. 33, 13 aout. 215-216 p. 1908.

19. Nelson, Frank C.
Cattle spray testing. (Report of cattle spray test committee before 27th mid-year meeting Nat'l. Ass'n. of Insecticides and Disinfectants Mfgrs., Chicago, Ill.) Soap and San. Chem. 17(8):92-97, 113, 120 120. 1941.

20. Pearson, A. M., Wilson, J. L., and Richardson, C. H.
Some methods used in testing cattle fly sprays. Jour. Econ. Ent. 26(1):269-274. 1933.

21. Pearson, Allen M.
The role of pine oil in cattle fly sprays. Del. Agr. Expt. Sta. Bul. 196 (Tech. Bul. 16). 63 p. 1935.

22. Peet, C. H. and Grady, A. G.
Studies in insecticidal activity. Jour. Econ. Ent. 21(4):612-617. 1928.

23. Peet-Grady Method.
Official method of the National Assn. Insecticide and Disinfectant Mfgrs. for evaluating liquid household insecticides. Blue book, 13th ed. Soap and San. Chem. 213 p. 1941.

24. Searls, Ed. M. and Snyder, Fred M.
The relation of viscosity to drop size and the application of oils by atomization. Jour. Econ. Ent. 29(6):1167. 1936.

25. Searls, Ed. M., and Snyder, Fred M.
Sprays for the control of flies on dairy animals and in dairy buildings. Wis. Ext. Serv. Sten. Cir. 209. 7 p. 1939.

26. Searls, E. Om.
Droplet size of insecticides. Soap and San. Chem. 27(2):94-96. 1941.

27. Smith, J. B.
The horn fly (Hematobia serrata). N. J. Agr. Expt. Sta. Bul. 62. 40 p. 1889.

28. Snedecor, George W.
Statistical Methods, 3rd ed. Iowa State College Press. 422 p. 1940.

29. United States Public Health Service.
Public Health Bul. 220, Milk Ord. and Code. p. 43, 50, 51, 84. 1939.

30. Ibid. p. 45 and 49.