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THE CHEMOTROPIC RESPONSES OF THE HOUSE FLY, THE GREEN-BOTTLE FLIES, AND THE BLACK BLOWFLY

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INTRODUCTION

Chemotropic tests with the screw-worm fly, *Cochliomyia macellaria* Fab., have been carried on for a number of years by the writers.[1]

This work was done principally for the purpose of finding suitable repellents with which to dress wounds on animals to prevent them from becoming infested with the screw worm, or to prevent reinfestations after an infestation of worms has been killed out. During these tests observations were made on the behavior of other species of flies toward the materials used.

The results of these observations are here presented with the thought that they might be of value in further studies of the chemotropism of insects, particularly flies, in devising repellents to protect man and animals from blood-sucking or annoying species, to keep flies away from food and out of camps and unscreened buildings, and to give information that might be of value in developing baits for trapping or poisoning the adult flies or for preventing the breeding of larvae in baits.

[1] BISHOPP, F. C., COOK, F. C., PARMAN, D. C., and LAAKE, E. W. PROGRESS REPORT OF INVESTIGATIONS RELATING TO REPELLENTS, ATTRACTANTS AND LARVICIDES FOR THE SCREW-WORM AND OTHER FLIES. Jour. Econ. Ent. 16: 222–224. 1923.
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LAAKE, E. W., PARMAN, D. C., BISHOPP, F. C., and ROARK, R. C. FIELD TESTS WITH REPELLENTS FOR THE SCREW-WORM FLY, COCHLIOMYIA MACELLARIA FAB., UPON DOMESTIC ANIMALS. Jour. Econ. Ent. 19: 536–539. 1926.
PARMAN, D. C., LAAKE, E. W., COOK, F. C., and ROARK, R. C. CHEMOTROPIC TESTS WITH THE SCREW-WORM FLY. U. S. Dept. Agr. Bul. 1472, 32 p. 1927.
ROARK, R. C., PARMAN, D. C., BISHOPP, F. C., and LAAKE, E. W. REPELLENTS FOR BLOWFLIES. Indus. and Engin. Chem. 19: 942–943. 1927.
PARMAN, D. C., LAAKE, E. W., BISHOPP, F. C., and ROARK, R. C. TESTS OF BLOWFLY BAITS AND REPELLENTS DURING 1926. U. S. Dept. Agr. Tech. Bul. 80, 15 p., illus. 1928.

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PROCEDURE

In these tests pint Mason jars were used as containers for the baits. Enough sand to make a layer 1 inch in depth was put in each jar, and on this 4 ounces of fresh meat was laid. A measured quantity of the material to be tested (5 grams of the solids and 5 cubic centimeters of the liquids) was then scattered over the surface of the meat. These amounts were sufficient to cover the surface of the meat rather thoroughly. Fresh beef liver was employed in most of the tests, but rabbit meat was used in some of them. In most instances a number of materials were tested simultaneously, and each material was exposed in two jars, and from two to five other jars were left untreated to serve as checks. Some of these experiments were conducted at Dallas, Tex., and others at Uvalde, Tex., the tests being made at different times of the year and during several seasons. Since these factors caused considerable variation in results, and an insufficient number of tests were made to weigh the variabilities, it has been thought best to combine all the data secured. In Dallas the jars were exposed under a shed at a packing plant, and their positions were interchanged after each observation. In the early tests at Uvalde the jars were set out on the ground in the shade of mesquite trees, but in the later ones they were exposed in a shed with all sides open, and the check and treated jars were placed in alternate positions. The distance between the jars ranged in different tests from 4 to 6 feet.

Most of the tests were begun about midday. Two observations were made on the first day; four on the second, third, and fourth days; and two on the fifth day, the tests being discontinued about noon of that day. This made the daily observations about two hours apart. At each observation the number of flies of each species in each jar was counted, and the presence of eggs or larvae was noted.

MATERIALS USED

The selection of materials to be tested was made from a wide range of organic and inorganic compounds, with the hope of gaining some information as to the reaction of the different species of flies to different groups or types of materials. The chemical compounds used were mainly chemically pure, and the essential oils and crude drugs were of the best commercial grade obtainable. The lubricating oil used as a diluent was automobile motor oil, specific gravity 0.930, viscosity at 104° F. 495 seconds Saybolt, manufactured from crude oils of different bases. The mineral oil used was a spindle oil with a specific gravity at 60° of about 0.88, and a boiling range from 569° to 750°. The petrolatum used was U. S. P. The pine products were made by destructive distillation except where otherwise noted.

RESULTS OF TESTS

In the following tables the attractiveness of the treated meat baits is compared with that of the check, or untreated baits, for the house fly (*Musca domestica* L.), the green-bottle flies (*Lucilia* spp.), and the black blowfly (*Phormia regina* Meig.). As the flies entering the jars were not killed it was not possible to determine the species of Lucilia with accuracy. In these tests *Lucilia sericata* Meig. and *L.*

cuprina Wd. were the predominant species found. In the following tables the number of flies of each species entering the jars with treated bait is compared with the number entering those with the untreated meat, the results being expressed as the percentage ratio or coefficient of efficacy. A percentage ratio of zero indicates perfect repellent action, a ratio of 100 no repellent effect, and more than 100 shows that the material makes the bait more attractive to the flies. Similar data were presented for the screw-worm fly, *Cochliomyia macellaria* Fab., in Department Bulletin No. 1472 [2] and Technical Bulletin No. 80.[2] Table 1 covers the complete list of the materials tested, and the tables following summarize the more outstanding results.

TABLE 1.—*Results of chemotropic tests with Musca domestica, Lucilia spp., and Phormia regina, Dallas and Uvalde, Tex.*

Compounds	Total number of treated jars	Musca domestica			Lucilia spp.			Phormia regina		
		Number of flies [a] in—		Percentage ratio [b]	Number of flies [a] in—		Percentage ratio [b]	Number of flies [a] in—		Percentage ratio [b]
		Treated jar	Check jar		Treated jar	Check jar		Treated jar	Check jar	
Hydrocarbons:										
Benzene	2	204	283	72.1	87	91	95.6	------	------	------
p-Cymene	7	47	136	34.6	17	30	56.7	------	------	------
Mineral oil	4	[c] 13.3	[c] 26	51.2	[c] 160	[c] 93	172.0	------	------	------
Naphthalene and kaolin, 1 to 9	2	143	143	100.0	133	105	126.7	------	------	------
Petrolatum	6	87	369	23.6	90	108	83.3	------	------	------
α-Pinene	5	4	123	3.3	14	28	50.0	------	------	------
o-Xylene	3	66	123	53.7	17	46	37.0	------	------	------
Bromides:										
Bromoform	7	1,018	482	211.2	233	209	111.5	30	132	22.7
α-Bromonaphthalene	5	90	448	20.1	27	152	17.8	8	123	6.5
p-Xylyl bromide	4	0	73	0	0	111	0	------	------	------
Chlorides:										
Benzyl chloride	6	13	81	16.0	26	127	20.5	------	------	------
Carbon tetrachloride	1	73	109	67.0	36	44	81.8	------	------	------
Chloroform	1	156	109	143.1	43	44	97.7	------	------	------
p-Dichlorobenzene	9	325	353	92.1	56	92	60.9	48	104	46.2
Hexachloroethane	2	9	104	8.7	6	53	11.3	------	------	------
Hexachloroethane and kaolin, 1 to 9	2	2	143	1.4	5	105	4.8	------	------	------
Pinene plus hydrochloric acid	5	21	103	20.4	8	37	21.6	------	------	------
Pinene hydrochloride	3	48	182	26.4	0	16	0	------	------	------
Pinene hydrochloride and kaolin, 1 to 9	2	2	143	1.4	5	105	4.8	------	------	------
p-Xylyl chloride	4	8	73	11.0	41	111	36.9	------	------	------
Iodides:										
Iodoform	4	179	522	34.3	105	211	49.8	19	139	13.7
Iodoform and kaolin, 1 to 4	1	49	107	45.8	23	36	63.9	------	------	------
Iodoform and kaolin, 1 to 9	2	15	143	10.5	8	105	7.6	------	------	------
Iodoform and petrolatum, 1 to 2	1	0	107	0	30	36	83.3	------	------	------
Alcohols:										
d-Borneol	3	102	277	36.8	32	86	37.2	------	------	------
Geraniol	4	461	351	131.3	97	115	84.3	160	159	100.6
α-Terpineol	2	38	104	36.5	8	53	15.1	34	102	33.3
Phenols:										
Carvacrol	6	150	308	48.7	41	105	39.0	29	135	21.5
Eugenol	9	116	290	40.0	26	115	22.6	70	184	38.0
Resorcinol	1	95	107	88.8	18	36	50.0	------	------	------
Safrol	12	268	848	31.6	82	288	28.5	65	274	23.7
Aldehydes:										
Butyraldehyde	4	434	315	137.8	94	76	123.7	------	------	------
Cinnamaldehyde	8	325	660	49.2	74	232	31.9	53	214	24.8
Crotonaldehyde	4	142	315	45.1	50	76	685.8	------	------	------
Formaldehyde	7	239	175	136.6	22	65	33.8	------	------	------

[a] Total number of flies of this species entering jars during entire period of exposure.
[b] Percentage ratio is determined by dividing the total number of flies in treated jar by the total number in check jar and multiplying by 100
[c] This figure is the average of number of flies in jars in several tests.

[1] See footnote 1.

TABLE 1.—*Results of chemotropic tests with Musca domestica, Lucilia spp., and Phormia regina, Dallas and Uvalde, Tex.*—Continued

Compounds	Total number of treated jars	Musca domestica			Lucilia spp.			Phormia regina		
		Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio
		Treated jar	Check jar		Treated jar	Check jar		Treated jar	Check jar	
Aldehydes—Continued.										
Furfural	17	151	818	18.5	106	305	34.8	23	291	7.9
Furfural and kaolin, 1 to 4	4	52	171	30.4	7	91	7.7			
Furfural and petrolatum, 1 to 5	3	4	153	2.6	0	43	0			
Heptaldehyde	5	154	320	48.1	52	86	60.5			
Salicylaldehyde	9	98	338	29.0	53	156	34.0	5	168	3.0
Ketones:										
Acetone	5	135	134	100.7	37	58	63.8			
Chlorine substituted ketones:										
Chloroacetone	6	8	76	10.5	23	139	16.5			
Chloroacetophenone	3	16	458	3.5	9	164	5.5	2	102	2.0
Chloroacetophenone and kaolin, 1 to 1	3	2	290	.7	10	79	12.7			
Chloroacetophenone and kaolin, 1 to 9	2	4	143	2.8	18	105	17.1			
Chloroacetophenone and petrolatum, 1 to 2	1	0	107	0	1	36	2.8			
Esters:										
Methyl salicylate	7	37	243	15.2	27	124	21.8	15	184	8.2
Halogen substituted esters:										
β-Chloroethyl acetate	4	16	73	21.9	32	111	28.8			
β-Bromoethyl acetate	6	13	81	16.0	27	127	21.3			
Ethers:										
β-Naphthylethyl ether	9	40	701	5.7	45	216	20.8	5	100	5.0
Nitro compounds:										
Nitrobenzene	16	178	652	27.3	68	249	27.3	7	231	3.0
Nitrobenzene and kaolin, 1 to 4	3	8	149	5.4	7	81	8.6			
Nitrobenzene and petrolatum, 1 to 5	2	1	115	.9	6	45	13.3			
Nitrocymene	9	342	711	48.1	105	310	33.9	25	215	11.6
Mixed nitro compounds:										
Chloropicrin and lubricating oil, 1 to 9	8	7	47	14.9	81	388	20.9			
Chloropicrin and lubricating oil, 1 to 49	4	9	73	12.3	28	111	25.2			
Picric acid	3	19	244	7.8	32	130	24.6			
Amines:										
Dimethylaniline	7	83	482	17.2	70	198	35.4	7	133	5.3
Miscellaneous nitrogenous compounds:										
Pyridine	10	228	732	31.1	164	255	64.3	2	171	1.2
Pyridine and lubricating oil, 1 to 9	6	13	37	35.1	257	358	71.8			
Sulphur compounds:										
Allyl isothiocyanate	9	118	713	16.5	52	288	18.1	1	148	.7
Allyl isothiocyanate and kaolin, 1 to 3	4	38	171	22.2	5	84	6.0			
Allyl isothiocyanate and petrolatum, 1 to 2	4	18	138	13.0	6	60	10.0			
Butyl mercaptan	3	189	458	41.3	96	164	58.5	43	102	42.2
Carbon disulphide	1	91	109	83.5	37	44	84.1			
Ethyl mercaptan	2	315	183	172.1	41	43	95.3			
Selenium compounds:										
Ethyl selenide	1	59	109	54.1	22	44	50.0			
Inorganic compounds:										
Antimony trichloride	2	75	183	41.0	23	43	53.5			
Arsenical solution (2 per cent dip)	1	127	109	116.5	28	44	63.6			
Borax	2	111	283	39.2	76	91	83.5			
Copper carbonate	6	20	306	6.5	34	170	20.0			
Copper carbonate and kaolin, 1 to 9	2	4	143	2.8	5	105	4.8			
Copper sulphate	3	62	179	34.6	46	127	36.2			
Kaolin	4	382	411	92.9	84	121	69.4			
Lead acetate	1	77	109	70.6	30	44	68.2			
Potassium sulphide	4	49	353	13.9	61	174	35.1			

TABLE 1.—*Results of chemotropic tests with Musca domestica, Lucilia spp., and Phormia regina, Dallas and Uvalde, Tex.*—Continued

Compounds	Total number of treated jars	Musca domestica			Lucilia spp.			Phormia regina		
		Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio
		Treated jar	Check jar		Treated jar	Check jar		Treated jar	Check jar	
Essential oils of botanical origin:										
Anise, star	11	84	691	12.2	64	326	19.6	41	139	29.5
Bergamot	1	84	174	48.3	20	47	42.6			
Bergamot and lubricating oil, 1 to 9	2	8	24	33.3	29	198	14.6			
Cade	11	56	398	14.1	49	219	22.4			
Cajuput	7	57	230	24.8	29	82	35.4			
Camphor	6	6	179	3.4	7	66	10.6	28	133	21.1
Camphor, white special	9	105	504	20.8	83	189	43.9			
Camphor by-product	18	263	1,214	21.7	111	503	22.1	46	289	15.9
Camphor by-product and bone meal, 1 to 3	1		107	9	0	36	0			
Camphor by-product and kaolin, 1 to 3	5	14	278	5.0	1	120	.8			
Camphor by-product and petrolatum, 3 to 1	4	5	245	2.0	0	9	0			
Cassia	7	242	267	90.6	42	108	38.9	42	120	35.0
Cassia, redistilled, and lubricating oil, 1 to 9	2	11	24	45.8	115	198	58.1			
Cedar leaf	2	51	283	18.0	100	91	109.9			
Cedar wood	5	97	202	48.0	75	113	66.4			
Cinnamon	12	81	718	11.3	52	277	18.8	2	139	1.4
Cinnamon and lubricating oil, 1 to 9	2	0	24	0	93	198	47.0			
Citronella	13	17	211	8.1	18	104	17.3			
Citronella and lubricating oil, 1 to 9	6	1	37	2.7	170	358	47.5			
Clove	10	71	513	13.8	49	206	23.8	9	132	6.8
Clove and lubricating oil, 1 to 9	8	11	47	23.4	185	383	47.7			
Clove bud	5	59	376	15.7	16	120	13.3			
Clove bud and petrolatum, 3 to 1	1	1	107	.9	0	12	0			
Clove bud and kaolin, 1 to 3	1	2	107	1.9	0	12	0			
Coriander	7	58	661	8.8	12	236	5.1	3	139	2.2
Cumin	10	18	132	13.6	5	60	8.3			
Eucalyptus	4	26	128	20.3	57	68	83.8			
Fennel	16	66	530	12.5	64	167	38.3	31	200	15.5
Fennel and lubricating oil, 1 to 9	6	3	37	8.1	247	358	69.0			
Geranium, rose	5	62	635	9.8	56	221	25.3	8	139	5.8
Geranium, rose, and lubricating oil, 1 to 9	2	1	24	4.2	47	198	23.7			
Lavender, garden (artificial)	1	28	174	16.1	23	47	48.9			
Lavender, spike	2	47	179	26.3	47	67	70.1			
Nutmeg	2	3	104	2.9	17	53	32.1			
Nutmeg and lubricating oil, 1 to 9	2	1	24	4.2	140	198	70.7			
Origanum	6	41	147	27.9	18	53	34.0			
Pennyroyal, American	11	18	204	8.8	35	96	36.5	5	100	5.0
Pennyroyal, American, and lubricating oil, 1 to 9	2	2	24	8.3	65	198	32.8			
Peppermint	7	15	103	14.6	4	25	16.0			
Sandalwood	6	81	656	12.4	99	226	43.8	45	139	32.4
Sassafras	8	54	440	12.3	62	200	31.0			
Sassafras, artificial	5	37	393	9.3	13	139	9.4			
Sassafras, artificial, and kaolin, 1 to 3	1	0	107	0	5	12	41.7			
Spearmint	9	120	844	14.2	70	279	25.1	5	220	2.3
Thyme	10	75	679	11.0	125	230	54.3	1	139	.7
Wormseed	11	41	130	31.5	5	46	10.9			
Miscellaneous vegetable materials:										
Angelica root	1	30	174	17.2	14	47	29.8			
Cinnamon powder	4	313	315	99.4	51	76	67.1			
Clove powder	12	125	846	14.8	47	348	13.5	2	200	1.0
Clove powder and petrolatum, 1 to 2	2	0	112	0	4	45	8.9			
Clove powder and kaolin, 1 to 4	1	24	107	22.4	0	36	0			
Clove powder and kaolin, 1 to 9	2	20	143	14.0	50	105	47.6			
Deer's-tongue leaves	1	73	174	42.0	24	47	51.1			
Derris powder	5	18	167	10.8	38	95	40.0			
Derris powder and kaolin, 1 to 9	2	9	143	6.3	21	105	20.0			

TABLE 1.—*Results of chemotropic tests with Musca domestica, Lucilia spp., and Phormia regina, Dallas and Uvalde, Tex.*—Continued

Compounds	Total number of treated jars	Musca domestica			Lucilia spp.			Phormia regina		
		Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio
		Treated jar	Check jar		Treated jar	Check jar		Treated jar	Check jar	
Miscellaneous vegetable materials—Continued.										
Lupulin	1	43	174	24.7	21	47	44.7			
Pennyroyal leaves	1	165	174	94.8	25	47	53.2			
Peppermint leaves	1	87	174	50.0	25	47	53.2			
Pyrethrum powder	6	103	345	29.9	37	128	28.9	1	99	1.0
Pyrethrum powder and kaolin, 1 to 9	2	13	143	9.1	77	105	73.3			
Sassafras bark	1	101	174	58.0	28	47	59.6			
Wormseed, American	2	33	118	28.0	3	53	5.7			
Pine products:										
Pinap	4	5	195	2.6	18	95	18.9			
Pinap and mineral oil, 1 to 9	6	0	37	0	197	358	55.0			
Pinap and pine tar oil, 1 to 1	2	47	167	28.1	29	59	49.2			
Pine oil, crude	2	59	349	16.9	58	120	48.3			
Pine oil, refined	8	5	369	1.4	37	219	16.9			
Pine oil, pure steam-distilled	10				31	211	14.7			
Pine oil, pure amber steam-distilled	3	34	354	9.6	33	130	25.4			
Pine oil No. 4	10	9	399	2.3	50	265	18.9			
Pine oil No. 4 and refined tar oil, 1 to 1	2	6	167	3.6	38	59	64.4			
Pine oil No. 4 and pine tar oil, 1 to 1	2	15	167	9.0	28	59	47.5			
Pine oil No. 4 and mineral oil, 1 to 9	2	3	24	12.5	106	198	53.5			
Pine tar	16	116	983	11.8	122	380	32.1	11	135	8.1
Pine tar, heavy	4	11	195	5.6	46	95	48.4			
Pine tar and borax 1 to 1	3	14	383	3.7	134	157	85.4			
Pine tar, borax, and kaolin, 1–1–2	1	2	107	1.9	14	36	38.9			
Pine tar, borax, and petrolatum, 1–1–2	1	0	107	0	1	36	2.8			
Pine tar, medium	4	3	195	1.5	16	95	16.8			
Pine tar, medium, and mineral oil, 1 to 9	2	2	24	8.3	114	198	57.6			
Pine-tar, thin	4	6	195	3.1	22	95	23.2			
Pine-tar oil	16	16	563	2.8	54	200	27.0	4	118	3.4
Pine-tar oil, commercial	10	11	591	1.9	22	268	8.2	0	125	0
Pine-tar oil, refined	9	43	716	6.0	98	284	34.5	0	113	0
Pine-tar oil and kaolin, 1 to 3	1	5	107	4.7	0	36	0			
Pine-tar oil and mineral oil, 1 to 9	4	5	34	14.7	108	228	47.4			
Pine-tar oil and petrolatum, 1 to 5	2	0	112	0	1	71	1.4			
Turpentine, crude	7	23	296	7.8	70	164	42.7	20	119	16.8
Turpentine, crude, and mineral oil, 1 to 9	2	5	24	20.8	56	198	28.3			
Wood-tar oil	6	4	118	3.4	2	38	5.3			
Wood creosote	7	19	209	9.1	17	88	19.3			
Wood creosote and glycerin, 1 to 1	2	100	183	54.6	49	43	114.0			
Mixtures with commercial pine-tar oil:										
Pine-tar oil and furfural, 1 to 1	2	9	167	5.4	6	59	10.2			
Pine-tar oil and furfural, 3 to 1	4	8	189	4.2	8	108	7.4			
Pine-tar oil and furfural, 10 to 1	2	7	175	4.0	5	41	12.2			
Pine-tar oil and furfural, 20 to 1	2	7	175	4.0	5	41	12.2			
Pine-tar oil, furfural, and camphor sassy, 3–1–1	2	6	175	3.4	2	41	4.9			
Pine-tar oil, furfural, and creosote dip, 3–1–1	2	1	175	.6	3	41	7.3			
Pine-tar oil, furfural, and fennel oil, 3–1–1	2	2	175	1.1	10	41	24.4			
Pine-tar oil, furfural, and safrol 3–1–1	2	2	175	1.1	1	41	2.4			
Pine-tar oil, furfural, and artificial sassafras oil, 3–1–1	2	1	175	.6	0	41	0			
Pine-tar oil, furfural, and star-anise oil, 3–1–1	2	2	175	1.1	0	41	0			
Pine-tar oil and safrol, 1 to 1	2	22	167	13.2	11	59	18.6			

TABLE 1.—*Results of chemotropic tests with Musca domestica, Lucilia spp., and Phormia regina, Dallas and Uvalde, Tex.*—Continued

Compounds	Total number of treated jars	Musca domestica			Lucilia spp.			Phormia regina		
		Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio	Number of flies in—		Percentage ratio
		Treated jar	Check jar		Treated jar	Check jar		Treated jar	Check jar	
Mixtures with commercial pine-tar oil—Continued.										
Pine-tar oil and safrol, 3 to 1	4	3	189	1.6	13	108	12.0			
Pine-tar oil and safrol, 10 to 1	2	4	175	2.3	5	41	12.2			
Pine-tar oil and safrol, 20 to 1	2	2	175	1.1	4	41	9.8			
Pine-tar oil and salicylaldehyde, 3 to 1	4	4	181	2.2	11	126	8.7			
Pine-tar oil, safrol, and salicylaldehyde, 3-1-1	2	4	167	2.4	2	59	3.4			
Pine-tar oil, safrol, and camphor sassy, 3-1-1	2	1	175	.6	4	41	9.8			
Pine-tar oil, safrol, and artificial sassafras oil, 3-1-1	2	2	175	1.1	5	41	12.2			
Pine-tar oil, safrol, and anise oil, 3-1-1	2	0	175	0	13	41	31.7			
Pine-tar oil, safrol, and fennel oil, 3-1-1	2	5	175	2.9	2	41	4.9			
Coal-tar creosotes:										
Coal-tar creosote	3	57	523	10.9	15	167	9.0			
Coal-tar creosote and kaolin, 1 to 3	1	0	107	0	0	36	0			
Coal-tar creosote and petrolatum, 1 to 5	2	0	112	0	3	45	6.7			
Miscellaneous: Bone meal	1	63	107	58.9						

In summarizing these tests, those in which fewer than 100 flies of the species in question were found in the check jars have been disregarded, as the number of flies present was considered to be so small that chance entered too largely as a factor.

Tests of mixtures are also not considered because these yielded erratic results. In many cases a chemical diluted with kaolin showed a higher repellent value than when used undiluted. More tests at times when flies are abundant would probably eliminate these inconsistencies.

With this elimination made of the inconclusive tests, Tables 2, 3, and 4 show the primary repellents having a coefficient of 10 or less.

TABLE 2.—*Best repellents for use against Musca domestica (summarized from Table 1)*

Material	Percentage ratio	Material	Percentage ratio
Pine oil, refined	1.4	β-Naphthylethyl ether	5.7
Pine tar, medium	1.5	Pine-tar oil, refined	6.0
Pine-tar oil, commercial	1.9	Copper carbonate	6.5
Pine oil No. 4	2.3	Turpentine, crude	7.8
Pinap	2.6	Picric acid	7.8
Pine-tar oil	2.8	Citronella oil	8.1
Nutmeg oil	2.9	Hexachloroethane	8.7
Pine tar, thin	3.1	Coriander oil	8.8
α-Pinene	3.3	American pennyroyal oil	8.8
Camphor oil	3.4	Wood creosote	9.1
Wood-tar oil	3.4	Artificial sassafras oil	9.3
Chloroacetophenone	3.5	Pine oil, pure amber, steam distilled	9.6
Pine tar, heavy	5.6	Rose geranium oil	9.8

TABLE 3.—*Best repellents for use against Lucilia spp. (summarized from Table 1)*

Material	Percentage ratio	Material	Percentage ratio
p-Xylyl bromide	0	Pine-tar oil, commercial	8.2
Coriander oil	5.1	Coal-tar creosote	9.0
Chloroacetophenone	5.5	Artificial sassafras oil	9.4

TABLE 4.—*Best repellents for use against Phormia regina. (Summarized from Table 1)*

Material	Percentage ratio	Material	Percentage ratio
Pine-tar oil, commercial	0	Nitrobenzene	3.0
Pine-tar oil, refined	0	Pine-tar oil	3.4
Allyl isothiocyanate	0.7	American pennyroyal oil	5.0
Thyme oil	.7	b-Naphthylethyl ether	5.0
Clove powder	1.0	Dimethylaniline	5.3
Pyridine	1.2	Rose-geranium oil	5.8
Cinnamon oil	1.4	a-Bromonaphthaleno	6.5
Chloroacetophenone	2.0	Clove oil	6.8
Coriander oil	2.2	Furfural	7.9
Spearmint oil	2.3	Methyl salicylate	8.2
Salicylaldehyde	3.0	Pine tar	8.1

DISCUSSION OF THE RESULTS

A close comparison of the reaction of the flies to the various materials is not possible on account of the very great difference in the relative abundance of the different species at the times the tests were made. Table 1 shows that of 192 tests there were only 167 in which as many as 100 of *Musca domestica* were found in the check jars; similarly, in only 93 tests were 100 or more of *Lucilia* spp. found in the check jars, and in only 40 tests were that number of *Phormia regina* found in the check jars.

In studying Table 1 it is noted that *Lucilia* spp. has a higher percentage ratio with the materials that are listed as best repellents for *M. domestica* and *P. regina* than do these flies. The materials that made the baits more attractive to *M. domestica* did not increase the attractiveness to *Lucilia* spp. to so great an extent as to *M. domestica*. This probably indicates that *Lucilia* spp. is not so chemotropically sensitive as the other flies. One species may be repelled to a great extent by a material added to the baits while another is attracted. In this series of tests bromoform had a repellent ratio of 22.7 for *P. regina*, while the ratio for *Lucilia* spp. was 111.5 and for *M. domestica* 211.2. Bromoform had a repellent ratio of 51.0 for *Cochliomyia macellaria*. (See Department Bulletin 1472, page 8.)

ATTRACTANTS

If those materials in the tests in which less than 100 flies of the species under observation were found in the check jars (Table 1) are omitted, only geraniol increased the attractiveness of the bait for *Phormia regina*, and that only slightly. Only one, bromoform, made the bait more attractive for *Lucilia* spp. As shown separately in Table 5, however, at least seven of the materials when added to the bait increased the attractiveness for *Musca domestica*.

TABLE 5.—*Material which increased the attractiveness of the baits to Musca domestica*

Material	Percentage ratio	Material	Percentage ratio
Bromoform	211.2	Formaldehyde	136.6
Ethyl mercaptan	172.1	Geraniol	131.3
Chloroform	143.1	Arsenic solution	116.5
Butyraldehyde	137.8		

Although the data here recorded might vary to a considerable extent from those of another series of like tests run at a different time and place, it is felt that they are indicative of what may be expected in further work along this line. They have been found useful in tests of field treatments for screw worms, and in work in trapping Hippelates, which will be reported in other papers.

SUGGESTIONS OF PRACTICAL IMPORT

Clove oil and clove powder are repellent to all four species of flies. These have been mixed with vegetable oils and used with good results in protecting fresh meats at camps. The mixtures were mopped over the meat and the excess wiped off when the meat was used. Other uses may be suggested by consulting the tables in this bulletin and in Department Bulletin 1472. By studying the ratios of flies visiting jars each day and the daily ratios of infestations, as shown in Table 1 of Bulletin 1472, some idea can be gained as to the most desirable material to use. These ratios show that some of the materials repelled all flies during the first or the first and second days of exposure, but were less effective later, and in consequence are indicated as rather poor repellents for the entire period. These results show that pine-tar oils are strongly repellent to the species of flies dealt with, and therefore lend force to the recommendations contained in Farmers' Bulletin 857, in which commercial pine-tar oil is advised as a dressing for the protection of wounds on animals from screw-worm and other blowflies.

Several of the essential oils, pine oils, pine-tar oils, and a few of the pure chemicals have been found to be fairly effective when lightly sprayed on vegetation or other objects and into the air about the camp site while meals were being prepared and served or while the occupants of the camp were at rest. The steam-distilled pine oils have been found to be effective in destroying the adults of some species of flies when sprayed as a mist over the flies or in closed rooms or barns containing them. These oils are probably somewhat toxic to man, as on some occasions severe headaches have developed after prolonged use of such oil sprays.

Some of the materials may be found useful in preserving bodies after catastrophes or in war times by preventing flies from breeding in them, and in treating carcasses harboring infectious diseases, to prevent the spread of such diseases by flies. The ratios of emergence from infested jars presented in Bulletin 1472 indicate the larvicidal values of the materials many of which are the same as those tested in the present work.

The results of the present work indicate that some materials may be added to baits to make them more effective in traps or as poisons.

SUMMARY

Continuing the studies on repellents which have been carried on by the writers for some years, the results of which have been published from time to time, tests were made in Texas at Dallas and Uvalde to determine the chemotropic responses of *Musca domestica*, *Lucilia* spp., and *Phormia regina* to a number of organic and inorganic materials, alone and in combinations. One hundred and ninety two of the tests have been presented in tabular form and briefly discussed.

Lucilia spp. apparently are not so chemotropically sensitive as the other flies. It was noted that one species might be attracted by a material added to the bait whereas another is repelled by it.

Pine-tar oils rank high in repellent value against all of the flies discussed herein.

Only geraniol was found to increase the attractiveness of the bait for *Phormia regina*, bromoform made the bait more attractive for *Lucilia* spp., and seven other materials made it more attractive for *Musca domestica*.

Clove oil and clove powder are used for protecting fresh meat at camps. Some of the materials have been used for repelling or destroying flies that were annoying at camps or in buildings. Other materials tested might be used in protecting bodies from flies in times of war or catastrophe.