A STUDY OF CERTAIN CHEMICALS FOR ATTRACTING JAPANESE BEETLES

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LIST OF ABBREVIATIONS

caproic		caproic acid
e. g.	exempli gratia	for example
et. al.	et alii	and others
i. e.	id est	that is
PEA		phenyl ethyl acetate
PEB		phenyl ethyl butyrate

INTRODUCTION

Since early times man has devised methods of combatting insect pests. An early method was the use of repellents. Crushed leaves, vegetable brews, animal excreta, smoke, and other materials have been used through the ages to repel insects. The use of attractants began with the advent of Christianity. About the time of Pliny and Aristotle people noted that insects possess a sense of smell, and that many insects distinguish one odor from another, but it was not until the eighteenth century that workers attempted to study the olfactory organs. The early writers placed these organs of smell on many locations, which included the spiracles, the tracheae, and parts of the head and its appendages. Toward the end of the nineteenth century through the work of Forel (10), Hauser, and others, the antennae were generally accepted. as being the seat of the olfactory sense. McIndoo (18), however, attempted to show that organs on the wings and legs of beetles were the only olfactory organs of these insects. Although his theory that none of the antennal structures serve as olfactory organs was not generally accepted, this work did show that organs of smell exist elsewhere than on the antennae. vonFrisch (25) and other later workers have shown that the principal olfactory organs are located on the antennae. Minnick (25) said that just as vertebrates are frequently creatures of their visual and auditory senses, so insects are largely creatures of their chemical senses. It is by these chemical senses that insects find their mates, and food for themselves and their offspring. Parker (29) classifies the chemical sense into three categories: the sense of smell, the sense of taste, and the common chemical sense. Of these, the sense of smell plays an important part in the life of insects.

During recent years there has been an increasing interest in the use of attractants and repellents in the field of insect control. Although many attractive materials, both natural and synthetic, have been studied critically, there is a need for more studies with the intent of developing more effective materials to attract insects. Since 1922 when Smith (35) and others demonstrated that geraniol and other chemicals were attractive to the Japanese beetle, Popillia japonica Newman, many workers have tried nearly two hundred chemicals attempting to find more efficient attractants. For many years traps baited with attractants have been used as a means of controlling Japanese beetles. These traps have been baited for more than ten years with a mixture consisting of nine parts of geraniol and one part of eugenol. During World War II shortages of these materials made their use almost prohibitive and it was necessary to seek practical substitutes.

Screening studies were initiated at the University of Maryland and have been conducted every year since 1941. These studies carried on by Cory, Langford, Muma, and the writer have produced formulae which are outstanding for attracting Japanese beetles. These works have also indicated that the ratio of materials used has important bearing upon the attractive values produced. It was found that when certain attractants are mixed together the attractive value is increased, but when others are added the values are depressed.

EARLY WORK ON JAPANESE BEETLE ATTRACTANTS

In the early studies on methods to control the Japanese beetle, it was noted that the adults, which are polyphytophagous, favored certain food plants and were strongly attracted to ripening fruit. In 1922 Richmond (32) and others tried many odorous compounds. Many essential oils were tested; some were found to be attractive, many were neutral in their effect, and still others appeared to be repellent. Constituents of these essential oils were studied, and geraniol proved to be outstanding in attracting the Japanese beetle. Later Metzger (21) showed geraniol to be a primary attractant for the Japanese beetle. He also showed that its effectiveness could be materially increased by the addition of eugenol. Therefore, the standard formula of nine parts geraniol and one part eugenol was used as the attractant from 1930 until shortly after 1940 when the raw materials for the production of these chemicals became very limited. This made it essential that substitute attractants be developed. Fleming and Chisholm (9) suggested that anethole could be substituted for geraniol and pimenta leaf oil for eugenol in the standard bait without significantly changing the catch of beetles. Muma _et al._ (26) showed that the geraniol-eugenol formula could be diluted half and half with a mixture of fifty per cent mineral oil in deodorized kerosene without materially reducing the effectiveness of the bait. Langford and Cory (14) modified the formula with the use of caproic acid and phenyl ethyl butyrate and got essentially the same efficiency as by using the standard geraniol-eugenol mixture. Langford and the writer (15) showed that phenyl ethyl acetate increased the attractiveness of bait combinations. Langford *et al.* (16) screened fifty-two chemicals normally present in host plants to find attractive materials. In these studies they found that when certain materials were combined there was a distinct increase in attraction, but when others were mixed there was a decrease, and some repelled.

PURPOSE

The purpose of this work was to make a systematic study of the relative values of six materials for attracting the Japanese beetle. They were chosen because they had shown premise in earlier tests and were compatible. Although much work has been done heretofore, there was a definite need for careful detailed comparisons of combinations in various proportions. These studies were conducted during the 1949 season at the University of Maryland, College Park. Calculations were made to find which of the baits were most economical as well as most attractive.

MATERIALS

<u>Sources of Odors</u>. Sources of odors in nature are varied. Dethier (5) classifies chemicals that are capable of stimulating the senses of insects into four groups: fundamental plant products, fundamental animal products, fermentation products, and decomposition products. He also states that the scents of practically all plants are due to the essential oils. These oils, often called volatile oils, are known to occur in all parts of plants.

Essential oils may occur in different parts of the same plant and may be found in the fibrovascular as well as the fundamental tissues. They are never present in a free state within a living cell. They may be found in the receptacles of a single cell or group of cells from which the protoplasm has disappeared, or in intercellular spaces formed by the decomposition of a number of adjacent cells, or by the separation of adjacent cell walls without injury to the cells themselves. Little is known of the status of essential oils in plants, but it is generally assumed that they are waste products. Their chief chemical constituents are: esters, alcohols, acids, aldehydes, ketones, phenols, phenol esters, lactones, benzene compounds, and nitrogen compounds. They may be aromatic or aliphatic compounds, saturated or unsaturated.

In these studies an alcohol (geraniol), a phenol (eugenol), an ether (anethole), two esters (phenyl ethyl acetate and phenyl ethyl butyrate), and one acid (caproic acid), were tested. These materials all have common characteristics in as far as they attract Japanese beetles; <u>i.e.</u>, they are all good attractants, the odors are lasting, and in addition no chemical reactions are likely to take place when they are mixed.

Geraniol. This is a cyclic alcohol closely related to the terpenes. It is found widely distributed throughout the plant kingdom and is a component of many essential oils. It is obtained commercially by the distillation of citronella, a fragrant grass which grown in southeastern Asia. Discovered early by Richmond (32) and others to be attractive to the adults of the Japanese beetle it remains as one of the most attractive materials yet found. Commercial geraniols are not chemically pure and the different grades vary in attractiveness. The best grades for use as attractants are those that fall in the higher range of the following specifications:

Specific gravity at 20° C. ———— 0.875–0.895
Total free alcohols as geraniol and citronellol ———— not less than 70%
Ester content ———— not less than 15%
Aldehydes as citronellol ———— not more than 3.5%
Solubility ———— 1 part in 2 parts 70% alcohol
Odor and color———— absence of any significant indication that foreign materials have been added.

Eugenol. This chemical belongs to the group of chemical compounds known as phenols. It is a colorless liquid and is the chief constituent of the oil of cloves. Eugenol is also found in essential oils of many plants, such as pimenta and star anise. It can be distilled in almost pure state. Samples of eugenol that meet the United States Pharmacopoeia standard vary little in their attractiveness to the Japanese beetle. This material was used as the standard or check and as a basis for indexing the beetle catches.

Anethole. This material is an ether which is commonly found in essential oils. It is a colorless liquid with a strong anise odor. Anethole distilled from anise, fennel, or pine oil, which meets the National Formularly specifications, is in use in Japanese beetle baits.

Phenyl ethyl acetate. This material is an ester of acetic acid. It is a colorless liquid with a delicate rose-like or peach-like odor.

Caproic acid. This fatty acid is found commonly in nature in animal secretions and excretions, and in living and decomposing green plants. It is a slightly yellow liquid with a strong goat-like odor or stench. Langford and Cory (14) found it to be an excellent attractant, but its effectiveness varied considerably with the source. Adulterations in the commercial products may change the attractive qualities of this material.

Phenyl ethyl butyrate. This ester of butyric acid is a colorless liquid with a faint musty odor of over-ripe apples. Muma et al. (28) found it to be a promising material for mixing with the geraniol-eugenol combination without materially lowering the attractive qualities.

Combinations. Richmond (32), Van Leeuwen (40), Fleming (8), and Langford et al. (16) have shown that certain mixtures of two or more attractants are superior to their components. Langford and his co-workers showed that in nineteen combinations of materials fifteen had attractive values that exceeded the attractive value of any one component. They also showed that one-third of these fifteen combinations had attractive values that exceeded the combined value of all the components of the mixture. In studies of the known attractants derived from four of the favored food plants of the Japanese beetle, they found acetic acid, caproic acid, eugenol, geraniol, and phenyl ethyl alcohol to be present in one or more. Richmond (32) found in his studies that some of the constituents of the essential oils were more attractive than the oils themselves. He concluded, therefore, that essential oils often contain masking constituents. In these studies the six materials chosen were shown to be good attractants for the Japanese beetle in their own rights; also when in combinations with the other materials they increased the attractiveness of the mixture, or served as a diluent for an attractant without materially lowering the subsequent beetle catch. These materials are not chemically active with one another except for one possible combination. There may be a slight esterification of geraniol by caproic acid. This reaction would be very slow, taking several months to complete at temperatures of less than one hundred fifty degrees Fahrenheit, and the resulting esters would retain the characteristic odors of the components.

METHODS

All tests were operated under field conditions in standardized traps. All traps were identical except for the chemicals used in bait bottles. To reduce possible errors from uneven evaporation three-quarter inch wicking was used in the bait bottles instead of the regular half inch wick and cork that are customarily used. Previous tests had proved the three-quarter inch wicks cut flush with the mouth of the bait bottle produced a minimum of fluctuation in evaporation of the test materials. Each of the six materials was mixed with one of the others, with two of the others, and with three of the others in varied proportions as shown in Tables I,V and VII. All tests containing geraniol, eugenol, anethole, and phenyl ethyl acetate were replicated four times and tests with caproic acid and phenyl ethyl butyrate twice. The experiments conducted with six materials in three hundred fifty combinations, of which seventy-nine were replicated four times and two hundred seventy-one twice. The traps were spaced at ten-foot intervals in linear batteries ten feet apart. In each of the fifty batteries a trap with eugenol as a standard was used. The number of traps in each battery was eight or ten, depending upon the number of proportions. All traps in each battery were rotated daily to overcome any effects of trap location or masking effects.

Whe

METHODS OF ANALYSIS

Beetle catches. The daily catches were summarized for each week for a period of five weeks as shown in Table I. All replications were summated so that the seasonal average could be obtained. This operation is shown in Table II. The average number of beetles caught by the various combinations and proportions of the materials is shown in Tables X, XI, and XII.

Analysis of beetle catches. In order to show whether there were significant differences in the beetle catches in the various combinations of materials, the data were analyzed statistically. Examples of these statistical procedures are shown in Tables III to IX, inclusive.

Indexing of beetle catches. For clarity in analyzing the data the beetle catches have been indexed on the basis of eugenol at 100. These indices are shown in Tables XIX, XX, and XXI.

The indices for the number of beetles caught by the individual materials for the years from 1943 through 1949 are appended in Table XVIII, and the tables of indices for the beetle catches of the various combinations and proportions of materials for the years of 1944 through 1948 are shown in Tables XIII to XVII, inclusive.

Determination of costs. Tables XXII, XXIII, and XXIV give estimated costs for those baits that appeared to be practical. They are based on current quotations. The range in prices was from seventy-five cents per pound for anethole to four dollars for phenyl ethyl butyrate.

Determination of Cost-index Ratio. High attractive indices may not always indicate that a combination of materials is practical, because its cost might be too high. Cost-index ratios were therefore calculated for the combinations that showed the highest indices; they are given in Tables XXV, XXVI, XXVII. The figures were obtained by dividing the estimated cost by the corresponding index.

Table XII. Indices of beetles caught with combinations
eugenol is 100.

Combinations of materials	Proportions 10 - 0	9 - 1	7 - 3	5 - 5
Geraniol-eugenol	124	164	144	143
Geraniol-anethole	167	104	81	70
Geraniol-PEA	152	213	195	122
Geraniol-caproic	116	196	130	159
Geraniol-PEB	171	128	64	212
Eugenol-anethole	100	78	92	88
Eugenol-PEA	100	241	231	187
Eugenol-caproic	100	113	107	155
Eugenol-PEB	100	119	159	91
Anethole-PEA	14	35	22	25
Anethole-caproic	15	16	23	41
Anethole-PEB	10	8	17	12
PEA-caproic	38	68	63	69
PEA-PEB	43	29	20	43
Caproic-PEB	22	20	29	23

of two materials when attractive value of

3 - 7	1 - 9	0 - 10	Empty
133	133	100	17
45	22	14	
78	73	49	
141	62	36	
119	163	31	
72	61	26	24
166	138	67	20
141	130	50	25
73	51	28	21
30	34	65	
31	38	25	
16	18	19	
69	64	28	
29	15	16	
19	37	26	

Table XI. Indices of beetles caught with combinations of three

Combinations of materials	Proportions 8-1-1	6-2-2	3'3'3'
Geraniol-eugenol-anethole	128	104	130
Geraniol-eugenol-PEA	294	282	310
Geraniol-eugenol-caproic	336	326	308
Geraniol-eugenol-PEB	197	178	147
Geraniol-anethole-PEA	150	94	59
Geraniol-anethole-caproic	140	85	118
Geraniol-anethole-PEB	36	30	15
Geraniol-PEA-caproic	157	181	148
Geraniol-PEA-PEB	179	124	105
Geraniol-caproic-PEB	120	64	84
Eugenol-anethole-PEA	198	195	161
Eugenol-anethole-caproic	142	191	192
Eugenol-anethole-PEB	56	67	67
Eugenol-PEA-caproic	231	260	260
Eugenol-PEA-PEB	149	194	182
Eugenol-caproic-PEB	94	98	96
Anethole-PEA-caproic	61	97	96
Anethole-PEA-PEB	19	21	26
Anethole-caproic-PEB	32	37	42
PEA-caproic-PEB	73	78	93

materials when attractive value of eugenol is 100.

2-6-2	2-2-6	1-8-1	1-1-8
137	101	127	105
338	292	321	95
211	238	224	251
142	128	105	106
143	56	28	60
113	60	96	113
20	17	117	31
86	96	99	107
56	67	52	98
120	77	56	103
138	140	132	145
216	172	165	123
65	67	39	65
176	328	189	230
223	169	158	125
109	182	189	92
62	79	72	83
36	29	42	39
46	48	45	55
78	74	66	64

Table XXI. Indices of beetles caught with combinations of four

Combinations of materials	Proportions			
	7-1-1-1	1-7-1-1	1-1-7-1	1-1-1-7
Geraniol-eugenol-anethole-PEA	306	231	188	162
Geraniol-eugenol-anethole-caproic	195	221	219	191
Geraniol-eugenol-anethole-PEB	97	101	67	68
Geraniol-eugenol-PEA-caproic	398	374	263	300
Geraniol-eugenol-PEA-PEB	295	296	246	272
Geraniol-eugenol-caproic-PEB	214	281	280	160
Geraniol-anethole-PEA-caproic	178	85	97	156
Geraniol-anethole-PEA-PEB	137	42	70	59
Geraniol-anethole-caproic-PEB	100	65	84	70
Geraniol-PEA-caproic-PEB	145	107	88	64
Eugenol-anethole-PEA-caproic	118	111	112	149
Eugenol-anethole-PEA-PEB	105	61	90	67
Eugenol-anethole-caproic-PEB	134	109	88	104
Eugenol-PEA-caproic-PEB	171	137	170	143
Anethole-PEA-caproic-PEB	57	51	70	70

materials when attractive value of eugenol is 100.

2'2'2'2'	4-2-2-2	2-4-2-2	2-2-4-2	2-2-2-4
185	212	293	198	189
188	209	156	167	172
80	80	75	65	91
270	228	297	281	295
207	282	278	297	326
225	219	248	304	313
154	130	108	105	101
44	111	58	93	107
115	102	90	103	82
144	159	112	111	175
181	150	159	168	162
81	97	93	116	109
129	87	97	93	92
195	225	213	151	200
80	63	90	61	50

DISCUSSION

Langford et al. (16) pointed out that mixtures of attractants, on the whole, were more attractive than any component. Richmond (32) stated that geraniol is clearly the primary attractant of the Japanese beetle, but combined with eugenol its effectiveness is increased. Tests at the University of Maryland (16) showed that some materials such as phenyl ethyl alcohol, caproic acid, and others gave additive values to the attractiveness of the mixtures to which they were added. Undoubtedly the proportions of the materials in a mixture had an influence on the effectiveness for attracting the insects. A nine to one mixture of geraniol and eugenol produced an index of 164 while equal amounts of these chemicals gave an index of 143. Therefore, in these studies data were analysed to show the relationship of mixing these chemicals with others and also to show the effect of the various proportions or concentrations of materials on the attractiveness of a mixture.

Evaporation may also be a factor influencing the attractive qualities of a mixture. However, tests run during the winter months and also concurrently with the adult beetle season in the summer of 1949, showed that all the materials, except phenyl ethyl butyrate, used in these tests evaporated at about the same rate. There were no significant differences in the rates of evaporation; although anethole, which was the poorest attractant when used alone, evaporated faster than the others. Phenyl ethyl butyrate evaporated much more slowly than the other materials. Based on the work of Muma et al. (27) and other unpublished work at the University of Maryland, it was assumed that most of these materials could be diluted up to fifty per cent with some inert, non-attractive substances, such as glycerine or a mixture of equal parts of white mineral oil and a highly deodorized kerosene, without materially reducing the attractiveness of the mixtures, provided the evaporation rates were nearly constant.

The discussion on the effectiveness of these materials will be on data taken during the 1949 adult Japanese beetle season. These data have been organized into indices of the number of beetles caught by the various combinations of materials and are shown in Tables XIX, XX, and XXI on pages 13 to 18, inclusive. However, the statistical analyses of data taken during the previous years confirm in most instances those taken in the 1949 season.

Geraniol. For years geraniol has been known as a primary attractant for the Japanese beetle. When used alone it caught more beetles than any of the materials used in the tests, the index being 124, when compared with eugenol with an attractive value of 100. When mixed in small amounts with the other chemicals geraniol increased the attractive qualities over the other chemical used alone. One part of geraniol mixed with nine parts of eugenol gave an index thirty-three per cent greater than eugenol alone. When geraniol was added to either anethole or phenyl ethyl acetate it gave an increased index fifty per cent greater than either of them alone; for caproic acid the increase was more than eighty per cent; and for phenyl ethyl butyrate nearly five hundred per cent. Geraniol gave an additive value to the mixtures with combinations of two or three materials. A mixture of nine parts of eugenol and one part of anethole gave an index of 78; when one part of geraniol was added to it there was an increase in attractiveness of nearly seventy per cent.

Likewise, when one part of geraniol was added to a mixture of eight parts of eugenol and one part each of anethole and caproic acid, with an index of 142, there was an increase in the attraction of over fifty per cent to an index of 221. Geraniol is not only a good attractant, but it has additive characteristics, which makes it one of the most important materials for attracting Japanese beetles.

<u>Eugenol</u>. This chemical can be considered one of the primary attractants, as very few single attractants gave greater catches of Japanese beetles. In these studies eugenol ranked second to geraniol. Like geraniol, eugenol has the characteristic of increasing the attractiveness of a mixture when added in small quanities. Richmond (32) noted that when eugenol was added to geraniol the attractiveness of the bait increased. Then for more than ten years the standard bait used in the thousands of traps used throughout the country was a mixture of nine parts of geraniol and one part of eugenol. In Table XIX the index number of 164 for this mixture is underscored. When one part of eugenol is added to nine parts of the other materials the attractive values are increased from thirty to one hundred sixty per cent. The increases of index values of such combinations were as follows: thirty per cent when added to geraniol, one hundred forty per cent when mixed with anethole, more than one hundred per cent when mixed with phenyl ethyl acetate, one hundred sixty per cent when added to caproic acid, and more than ninety per cent when used with phenyl ethyl butyrate. Eugenol produced also an additive value when mixed with combinations of two or more materials. When one part of eugenol was mixed with a combination of nine parts of geraniol and one part of anethole, which mixture has an index of 104, the attractive value

was increased to 128. When one part of eugenol was added to a mixture of nine parts of phenyl ethyl acetate and one part of caproic acid, with an index of 68, there was an increase of more than the index value of eugenol used alone; the index value of the eugenol-phenyl ethyl acetate-caproic acid combination was 189. Also, when one part of eugenol was added to a mixture of eight parts geraniol and one part each of anethole and phenyl ethyl acetate, which has an index of 150, the attractiveness of the mixture more than doubled to an index of 306.

Anethole. Anethole with an attractive index of 15, when compared with the attractive value of eugenol at 100, was quite low; it caught about as many beetles as an unbaited trap. However, when anethole was mixed in equal parts with eugenol the resulting combination had an index of only twelve per cent less than that of eugenol alone; however, the cost-index ratio was reduced from 200 for eugenol to 157 for the mixture. When anethole was mixed with equal parts of caproic acid, the resulting index was equal to the sum of the indices for the two materials, and sixty per cent greater than the index of caproic acid alone; also, the cost-index ratio was reduced from 375 for caproic acid to 256 for the mixture. When eight parts of anethole were mixed with two parts of equal amounts of eugenol and phenyl ethyl acetate, which had an index of 187 for the combination, the attractive value was reduced only about twenty-five per cent. The cost-index ratio was reduced from 101 for the original combination to 53 for the mixture with anethole. This combination has been used for bait in Japanese beetle traps throughout Maryland during the last two years.

Phenyl ethyl acetate. Langford and the writer (15) found that this chemical improved the attractive qualities of mixtures of geraniol and eugenol or anethole and eugenol. Used alone phenyl ethyl acetate was only fairly attractive for the Japanese beetle. It gave, however, additive attractive values when mixed in small proportions with the other materials. When one part of this chemical was added to nine parts of geraniol the index for the mixture was forty per cent greater than the index for geraniol alone and greater than the sum of the indices for the two materials. In mixtures with eugenol, anethole, or caproic acid, the additive value of this chemical was even greater than with geraniol. The index for a combination of nine parts of eugenol and one part of phenyl ethyl acetate was 241 or nearly two and one half times the index for eugenol alone. This index of 241 was also about forty-five per cent greater than the sum of the indices for the materials when used alone. The additive characteristic of phenyl ethyl acetate carried through when added to mixtures of the materials. When one part of phenyl ethyl acetate was added to a mixture of nine parts of geraniol and one part of eugenol, which gave an index of 164, the catch of beetles was about eighty per cent greater, with an index of 294. Likewise, when one part of phenyl ethyl acetate was added to a mixture of eight parts of geraniol and one part each of eugenol and anethole, which had an index of 128, the attractive value jumped to 306. When one part of this material was added to a mixture of eight parts of anethole and one part of phenyl ethyl butyrate, which had an index of 32, there was an increased attractive value of eighty per cent.

Caproic acid. This material was a fair attractant when used alone, being only about forty per cent as attractive as eugenol. However, caproic acid increased the attractive values when added to the other materials, except anethole. When caproic acid was added to anethole in small quantities there was little or no additive value to the attractiveness of the mixture. Caproic acid increased the indices nearly seventy per cent for geraniol, thirteen per cent for eugenol, eighty per cent for phenyl ethyl acetate, and about forty-five per cent for phenyl ethyl butyrate. Caproic acid also increased the attractive values of most mixtures. For example, when one part of caproic acid was mixed with a combination of nine parts of geraniol and one part of eugenol the attractive value was approximately twice that of the geraniol-eugenol combination. However, in some mixtures the addition of caproic acid did not add to the value, but was neutral or detracted from it. When one part of caproic acid was added to a mixture of eight parts of eugenol and one part each of anethole and phenyl ethyl acetate, with an index of 198, the attractive value was reduced to 118. Caproic acid had an additive value when mixed with many materials or combinations of materials, but the results varied and caproic acid masked the attractiveness of some combinations.

Phenyl ethyl butyrate. This material had about the same attractive index as caproic acid. Phenyl ethyl butyrate, like anethole, did not generally add much to the attractive value when mixed with the other materials. When added in small amounts to anethole or caproic acid the resulting indices were about the same. When one part was added to nine parts of geraniol or phenyl ethyl acetate the resulting indices were about twenty-five per cent less than the value of the other materials used alone. However, when one part was added to nine parts of eugenol the index was nearly twenty per cent greater than the one for eugenol.

When phenyl ethyl butyrate was mixed with equal parts of the other materials, except geraniol, there was little or no change in the attractive values. When mixed in equal parts with geraniol the catch was nearly twenty per cent greater than for geraniol. When phenyl ethyl butyrate was added to combinations of two or three materials the results were variable but usually the resulting indices were about the same or less. When eight parts of phenyl ethyl butyrate were added to two parts of a combination of equal amounts of geraniol and eugenol, which had an index of 143, there was only a slight reduction in attractive quality. However, when seven parts were added to three parts of a combination of equal amounts of geraniol, eugenol, and anethole, there was nearly a fifty per cent reduction in the catch.

Attractive values of combinations of the materials. Table XVIII shows that the range of indices for the materials used alone varied from 15 for anethole to 124 for geraniol. The other indices for the individual materials were 100 for eugenol, 61 for phenyl ethyl acetate, and 38 for caproic acid or phenyl ethyl butyrate. Indices for combinations of two of these attractants ranged from 8 for the mixture of nine parts of anethole and one part of phenyl ethyl butyrate to 241 for a combination of nine parts of eugenol and one part of phenyl ethyl acetate. The indices for combinations of three materials ranged from 17 to 338 and those for mixtures of four chemicals from 42 to 398. These show that in the combinations of two materials the indices are generally higher than the index for one of the components. The indices of the combination of three materials average nearly forty per cent higher than the averages of the indices for the combinations of two materials, and the indices for combinations of four materials average about fourteen per cent higher than those for the three material combinations. In these studies the combination of three or four materials seems to be the best.

<u>Costs</u>. Tables XXIII to XXIV show that the range of cost for the most effective combinations was from eight and six-tenths cents to thirty-eight cents per forty-gram bait. Tables XIX to XXI show that the range of indices was from 8 to 398. The ratios of the cost of the better combinations to their indices give a means of gauging the most economical mixtures to use: the lower the ratio the better the bait. Tables XXV to XXVII give these ratios. Table XXVIII lists the most promising combinations with their indices and cost-index ratios. The highest index and the lowest cost-index ratio was a mixture of seven parts of geraniol and one part each of eugenol, phenyl ethyl acetate, and caproic acid.

<u>Attractiveness to male and female beetles</u>. The chemicals under discussion are feeding-type attractants. Although it is generally considered that food preference of the two sexes is the same, it is not true of all insects. The female mosquitoes feed on blood while males live on fruit or plant juices. In literature there are several examples where one sex is attracted to a certain food-type bait material more than the opposite sex. Worthley and Nicholas (44) showed that more female codling moths than males were attracted to a standard bait with anethole added, and Wisting and Haskins (42) noted that female houseflies were attracted to ammonia in greater numbers than males. On the other hand ethyl alcohol attracted more male houseflies than females. Counts to determine sexes of trapped beetles made at random at weekly intervals showed that none of these six materials or any combinations of them was more attractive to one sex than the other.

The best combinations of materials. Of the three hundred fifty combinations of materials used in these tests, one hundred one mixtures showed better catches of Japanese beetles than the standard geraniol-eugenol mixture. Thirty-six combinations were fifty per cent better and six mixtures were approximately twice as efficient as the standard bait. In Table XXVIII on page 28 the combinations are arranged in the descending order of their indices. The cost-index ratio gives a direct method of determining which mixtures combine high effectiveness with low cost. The lower the ratio the better the combination—the best combination of two materials was eugenol with a small amount of phenyl ethyl acetate. The addition of a small amount of caproic acid to this mixture produced the highest index for three materials, but the most effective combination was a mixture of two parts each of eugenol and phenyl ethyl acetate and six parts of caproic acid. The best combination of all consisted of seven parts of geraniol and one part each of eugenol, phenyl ethyl acetate, and caproic acid.

Table XXVIII. The best combinations of materials for attracting the Japanese beetle.

Combinations and proportions	Cost-index ratio	Index
Geraniol-eugenol-PEA-caproic- (7-1-1-1)	44	398
Geraniol-eugenol-PEA- (2-6-2)	65	338
Geraniol-eugenol-caproic- (8-1-1)	53	336
Eugenol-PEA-caproic- (2-2-6)	48	328
Geraniol-eugenol-anethole-PEA- (7-1-1-1)	56	306
Eugenol-PEA- (9-1)	82	241
Geraniol-caproic- (9-1)	90	196
Geraniol-PEA- (7-3)	84	195
Geraniol-eugenol- (9-1) (Standard bait)	111	164

CONCLUSIONS

An index, calculated for each material and for each mixture of materials by the comparison of the number of Japanese beetles caught with the number attracted by eugenol as a standard, is a reliable means of evaluating its attractiveness. Geraniol and eugenol have high indices; they are classified as primary attractants. Phenyl ethyl acetate has an index a little less than the mid-point between the primary attractants and caproic acid and phenyl ethyl butyrate. The indices for these materials are about forty per cent that of eugenol. The index for anethole is quite low, being only slightly better than that for an unbaited trap.

Combinations of some of the attractants give indices much higher than the sum of the indices of the components. Geraniol, eugenol, and phenyl ethyl acetate have high additive values; the addition of a small amount of one of these materials increases the index of a mixture considerably, often doubling it. Caproic acid gives additive value in many combinations and phenyl ethyl butyrate in very few, generally adding or subtracting little. Anethole is a good adjunct for mixtures prepared with phenyl ethyl acetate, caproic acid, and eugenol. It serves as an efficient bulking agent, sustaining a large percentage of the attractiveness when these chemicals are used in relatively small amounts.

The number of attractive chemicals in a formulation may influence its attractiveness. In the combinations where two, three, or four chemicals were mixed the attractiveness was increased progressively. The progressive increases in indices were as follows: one chemical (geraniol), 124; two chemicals (eugenol and phenyl ethyl acetate), 241; three chemicals (geraniol, eugenol, and phenyl ethyl acetate), 338; four chemicals (geraniol, eugenol, phenyl ethyl acetate, and caproic acid), 398.

None of these materials shows any specificity in attracting either sex.

A cost-index ratio shows the relationship between the effectiveness and the costs of any combination. The lowest ratio is that of seven parts of geraniol and one part each of eugenol, phenyl ethyl acetate, and caproic acid. The cost-index ratio of this combination is only forty per cent of the ratio for the geraniol-eugenol standard bait mixture; *i.e.*, its index is over twice as high and cost per beetle caught is only half as much.

Table I. Record of beetles caught. Battery 1 of geraniol-eugenol test.

Materials of Proportions	No. of beetles caught per week. 1st.	2nd	3rd	4th	5th	Average	Indices*
Geraniol 10 parts	1582	565	1567	2180	555	1290	118
Geraniol-eugenol-(9-1)	1485	865	1996	2475	537	1472	135
Geraniol-eugenol-(7-3)	1675	772	1550	2760	345	1420	130
Geraniol-eugenol-(5-5)	1741	1390	1360	1965	298	1351	124
Geraniol-eugenol-(3-7)	1175	715	2435	2410	303	1408	129
Geraniol-eugenol-(1-9)	775	520	3106	2110	310	1364	125
Eugenol 10	1136	490	2275	1325	225	1090	100
Empty	147	130	104	360	51	158	14
Totals	9,716	5,447	14,393	15,585	2,624		

*attractive value of eugenol is 100

Table II. Record of beetles caught in the geraniol-eugenol tests. (Totals for four replications)

Materials and Proportions	No. of beetles caught per week 1st	2nd	3rd	4th	5th	average per trap per week	Indices*
Geraniol 10 parts	4004	2710	3700	5110	1032	828	125
geraniol-eugenol-(9-1)	5005	3385	5359	6808	1187	1087	164
Geraniol-eugenol-(7-3)	3894	3247	5007	5895	919	948	143
Geraniol-eugenol-(5-5)	4887	3570	5013	4506	858	942	142
Geraniol-eugenol-(3-7)	3980	2515	5446	4808	839	879	133
Geraniol-eugenol-(1-9)	2863	2465	6658	4694	940	881	133
Eugenol 10	3150	1569	5209	2604	727	663	100
Empty	421	555	353	834	282	122	18
Totals	28,204	20,106	36,745	35,259	6,784		

*attractive value of eugenol is 100

Table III. Analysis of the beetles caught by the combination of geraniol and anethole.

Proportions	Replications 1	2	3	4	Mean	Cost per bait
10 - 1	3970	1877	2724	5235	3451	$0.180
9 - 1	2556	1489	2154	2421	2155	.170
7 - 3	4006	717	1082	882	1671	.149
5 - 5	2488	431	933	1924	1444	.128
3 - 7	1694	366	653	990	926	.107
1 - 9	619	285	386	532	455	.086
0 -10	253	288	328	270	285	.075

Least significant difference between proportion means at 5% = 1086

Analysis of Variance

Source of Variations	Degree of Freedom	Sums of Squares	Variance	F
Replications	3	8,477,470		
Proportions	6	28,661,728	4,776,955	8.93*
Error	18	9,628,050	534,892	
Total	27	46,767,248		

*F value required for significance at 5% point is 2.66
Standard error of differences = 517.15

Table IV. Analysis of the beetles caught by combinations of eugenol and PEA.

Proportions	Replications 1	2	3	4	Mean	Cost per bait
10 - 0	4157	1229	2013	2560	2482	$0.200
9 - 1	11228	4319	3575	4796	5979	.198
7 - 3	11050	3561	4120	4903	5908	.193
5 - 5	6205	3621	5119	3632	4644	.188
3 - 7	5058	2644	4609	4175	4121	.183
1 - 9	4326	2196	3593	3647	3418	.178
0 - 10	3245	1016	1103	1286	1662	.175

Least significant difference between proportion means at 5% = 2032

Table V. Analysis of the beetles caught by combination of eugenol, anethole and PEA.

Proportions:	Replications					
	1	2	3	4	Means	Cost per bait
8-1-1	4102	7245	3850	5259	5114	$0.185
6-2-2	3155	8754	3818	4478	5051	.170
3'3'3'	3544	6905	3169	3053	4168	.150
2-6-2	2845	4556	4095	2755	3563	.105
2-2-6	2142	6376	3415	2577	3627	.160
1-8-1	2210	6397	2860	2154	3405	.098
1-1-8	2648	5403	4135	2845	3758	.168

Least significant difference between proportion means at 5% =1143.

Table VI. Analysis of the beetles caught by combination of materials geraniol, eugenol and PEA.

Proportions:	Replications 1	2	3	4	Means :	Cost per bait
8-1-1 :	52220	7710	5635	4578	5786	$0.182
6-2-2 :	5775	7035	5375	4025	5552	.183
3'-3'-3'	7070	7135	6245	3967	6104	.185
2-6-2	3990	10140	8390	4061	6645	.191
2-2-6	3093	10185	5815	3907	5750	.181
1-8-1	3095	9324	6695	6164	6319	.196
1-1-8 :	2415	4919	4500	3534	3842	.178

Least significant difference between proportion means at 5% = 2021

Table VII. Analysis of the beetles caught by combination of materials geraniol, eugenol, anethole and PEA.

Proportions	Replications 1	2	3	4	Means	Cost per bait
7-1-1-1	2980	7310	9428	11974	7923	$0.171
1-7-1-1	2178	7434	4525	9795	5983	.183
1-1-7-1	988	5277	3925	9325	4879	.108
1-1-1-7	1129	7567	3722	4367	4196	.168
2'2'2'2'	1466	6945	4885	5896	4798	.158
4-2-2-2	1699	8890	6140	5225	5488	.162
2-4-2-2	1750	11497	11709	5385	7585	.166
2-2-4-2	1317	8582	6535	4106	5135	.141
2-2-2-4	1498	6960	6098	5072	4907	.161

Least significant difference between proportion means at 5% = 2882

Table VIII. Beetles caught by combination of 2,3, or 4 materials.

Combinations and Proportions.	Replications 1	2	3	4	Means	Cost for bait
Geraniol 9 anethole 1	2556	1489	2454	2421	2155	.170
Eugenol 8-anethole 1-PEA 1	4102	7245	3850	5259	5114	.185
Geraniol 7-eugenol 1-anethole 1-PEA 1	2908	7310	9428	11975	7923	.171

Least significant difference between combination means at 5% level is 4128.

Table IX. Beetles caught by combinations of equal parts of 2,3, or 4 materials.

Combinations and Proportions	Replications 1	2	3	4	Means	Cost for bait
Geraniol 5-anethole 5	2488	431	933	1924	1444	.128
Eugenol 3'-anethole 3'-PEA 3'	3544	6905	3169	3053	4168	.150
Geraniol 2'-eugenol 2' anethole 2' PEA 2'	1466	6945	4885	5896	4798	.167

Least significant difference between combination means at 5% level is 3243.

Table X. Average number of beetles caught per trap
two materials.

Combination of materials	10 - 0	9 - 1	7 - 3	5 - 5
Geraniol-eugenol	3881	5139	4511	4494
Geraniol-anethole	3451	2155	1671	1444
Geraniol-PEA	3910	5478	5014	3141
Geraniol-caproic	2924	4916	3256	3988
Geraniol-PEB	4388	3282	1651	1836
Eugenol-anethole	2092	1628	1926	4644
Eugenol-PEA	2482	5979	5908	4175
Eugenol-caproic	2693	3043	2867	3764
Eugenol-PEB	4157	4934	6610	3764
Anethole-PEA	402	1015	645	730
Anethole-caproic	507	553	820	1420
Anethole-PEB	469	378	812	579
PEA-caproic	1367	2475	2303	2505
PEA-PEB	2957	2012	1378	2918
Caproic-PEB	1521	1398	2011	1567

with the combinations of

3 - 7	1 - 9	0 - 10	Eugenol 10	Empty
4169	4170	3133		541
926	455	285	2073	
1996	1882	1263	2570	
3542	1566	907	2511	
3042	4170	799	2564	
1497	1278	546		492
4121	3418	1662		506
3789	3510	1348		672
3023	2100	1180		875
863	993	1876	2893	
1098	1332	873	3500	
799	875	925	4915	
2515	2323	1005	3636	
1980	1011	1095	6857	
1332	2525	1759	6857	

Table XI. Average number of beetles caught per trap

Combinations of materials	Proportions		
	8-1-1	6-2-2	3'3'3'
Geraniol-eugenol-anethole	2869	2319	2896
Geraniol-eugenol-PEA	5786	5552	6104
Geraniol-eugenol-caproic	5478	5325	5022
Geraniol-eugenol-PEB	2820	2550	2100
Geraniol-anethole-PEA	3057	1909	1192
Geraniol-anethole-caproic	2467	1496	2090
Geraniol-anethole-PEB	607	502	256
Geraniol-PEA-caproic	4472	5169	4230
Geraniol-PEA-PEB	3651	2534	2150
Geraniol-caproic-PEB	2445	1313	1718
Eugenol-anethole-PEA	5114	5051	4168
Eugenol-anethole-caproic	3736	5030	5064
Eugenol-anethole-PEB	1160	1392	1391
Eugenol-PEA-caproic	6566	7393	7409
Eugenol-PEA-PEB	2291	2987	2805
Eugenol-caproic-PEB	1444	1500	1483
Anethole-PEA-caproic	1453	2297	2278
Anethole-PEA-PEB	216	234	297
Anethole-caproic-PEB	357	413	477
PEA-caproic-PEB	822	886	1047

with combinations of three materials.

				eugenol
2-6-2	2-2-6	1-8-1	1-1-8	10
3054	2250	2842	2334	2234
6645	5750	6319	3842	1967
3442	3877	3647	4094	1632
2036	1831	2940	1510	1431
2905	1232	567	1214	2035
1992	1068	1701	1997	1767
335	288	292	529	1702
2466	2747	2830	3050	2857
1137	1373	1053	1990	2040
2453	1561	1143	2095	2040
3563	3627	3405	3758	2588
5696	4526	4336	3235	2632
1344	1395	815	1336	2071
5012	9344	5377	6565	2846
3432	2599	2438	1929	1539
1677	2796	2907	1412	1539
1471	1879	1697	1962	2366
412	330	469	439	1131
523	539	509	624	1132
883	838	741	721	1131

Table XII. Average number of beetles caught per trap

Combinations of materials	Proportions 7-1-1-1	1-7-1-1	1-1-7-1	1-1-1-7
Geraniol-eugenol-anethole-PEA	7923	5963	4879	4196
Geraniol-eugenol-anethole-caproic	4636	5260	5294	4540
Geraniol-eugenol-anethole-PEB	872	906	599	613
Geraniol-eugenol-PEA-caproic	11673	10979	7708	8795
Geraniol-eugenol-PEA-PEB	2655	2665	2220	2452
Geraniol-eugenol-caproic-PEB	2302	3025	3014	1719
Geraniol-anethole-PEA-caproic	5370	2555	2929	4705
Geraniol-anethole-PEA-PEB	1477	456	748	633
Geraniol-anethole-caproic-PEB	1071	698	698	755
Geraniol-PEA-caproic-PEB	3416	2519	2073	1500
Eugenol-anethole-PEA-caproic	3881	3653	3690	4914
Eugenol-anethole-PEA-PEB	1684	989	1452	1086
Eugenol-anethole-caproic-PEB	2158	1759	1414	1675
Eugenol-PEA-caproic-PEB	2764	2199	2738	2307
Anethole-PEA-caproic-PEB	914	815	1134	1126

with combinations of __four__ materials.

2'2'2'2'	4-2-2-2	2-4-2-2	2-2-4-2	2-2-2-4	Eugenol 10
4798	5488	7585	5135	4907	2591
4471	4977	3708	3976	4091	2377
716	718	678	583	819	901
7937	6700	8715	8247	8648	2936
1865	2542	2505	2672	[illegible]	901
2417	2354	2670	3272	3372	1076
4654	3919	3269	3181	3053	3024
473	1196	623	1000	1156	1076
1235	1094	971	1107	877	1076
3402	3755	2639	2617	4120	2358
5965	4929	5220	5526	5343	3291
1311	1560	1504	1871	1763	1611
2073	1396	1567	1504	1582	1611
3145	3627	3426	2428	3221	1611
1297	1008	1457	977	811	1611

Table XIII. Indices of beetles caught in <u>1944</u> when the attractive value of geraniol-eugenol (9-1) mixture is 100.

Materials	Proportions			Empty
	2 - 8	1- 9	0 - 10	
Geraniol-anethole	65	51		
Geraniol-capreic	77	107		
Geraniol-PMB		78		
Eugenol-anethole	83		39	
eugenol-capreic	53	81	30	
Eugenol-PMB		73	54	7

Table XIV. Indices of beetles caught in 1945 when the attractive value of geraniol-eugenol (9-1) mixture is 100.

Materials	Proportions				
	9-1	8-2	5-5	2-8	1-9
Geraniol-caproic				79	79
Geraniol-PEB					68
Eugenol-anethole					71
Eugenol-PEA	145				
Eugenol-caproic				33	33
Eugenol-PEB			123	56	109
Anethole-caproic	12		41		56
Anethole-PEB	8		65		20
Caproic-PEB		97	91		47

Materials	8-1-1	1-8-8	1-1-8	3'3'3'	½-½-9	½-9-½	1-4-4	4-4-1	2-4-4
Geraniol-eugenol-caproic			173		71				
Geraniol-eugenol-PEB	144		222	186					
Geraniol-anethole-caproic							182		
Eugenol-anethole-caproic							247		133
Eugenol-anethole-PEB		84				114			
Eugenol-caproic-PEB		285				301		95	

Materials	4-1-4-1	1-4-4-1	2/3-2/3-8-2/3	½-4'-4'-½
Geraniol-eugenol-anethole-PEB			123	
Geraniol-eugenol-caproic-PEB	232		175	
Eugenol-anethole-caproic-PEB		67		279

Table XV. Indices of beetles caught in 1946 when the attractive value of geraniol-eugenol (9-1) mixture is 100.

Materials	9-1	8-2	6-4	5-5	4-6	2-8	1-9
Geraniol-eugenol		91					
Geraniol-PEA						90	
Geraniol-caproic						64	47
Eugenol-anethole							130
Eugenol-PEA						101	
Eugenol-caproic						30	33
Eugenol-PEB	73						
Anethole-PEA		17					
Anethole-caproic	26	27	38	44	37	30	
Anethole-PEB		13					
PEA-caproic		22					
Caproic-PEB	25	26					

Materials	8-1-1	1-8-1	1-1-8	2-6-2	2-4-4	1-4'4'	3'3'3'	½-9-½
Geraniol-eugenol-anethole			74					
Geraniol-eugenol-PEA	174							
Geraniol-eugenol-caproic	82		47					
Geraniol-eugenol-PEB	112		110				111	
Geraniol-anethole-caproic						65		
Geraniol-caproic-PEB		73						
Eugenol-anethole-PEA		46						
Eugenol-anethole-caproic				69	81	85		
Eugenol-anethole-PEB		99						81
Eugenol-PEA-caproic			99					
Eugenol-caproic-PEB		63		70				60

Materials	2/3-2/3-4-4-2/3	2/3-2/3-8-2/3	1-4'-4'-1
Geraniol-eugenol-anethole-PEB		96	
Geraniol-eugenol-anethole-caproic-PEB	84		
Geraniol-eugenol-PEA-PEB		97	
Eugenol-anethole-caproic-PEB		78	95

Table XVI. Indices of beetles caught in 1947 when the attractive value of geraniol-eugenol (9-1) mixture is 100.

Materials	Proportions: 9 - 1	2 - 8	1 - 9	Empty
Geraniol-caproic		76		
Eugenol-anethole			41	16
Eugenol-PEA		52	191	
Eugenol-caproic	36	84		

Materials	9-½-½	8-1-1	1-8-1	1-1-8	½-9-½
Geraniol-eugenol-PEA		221		130	
Geraniol-eugenol-caproic	113				
Geraniol-eugenol-PEB				71	
Eugenol-caproic-PEB			56	45	
Eugenol-PEA-caproic			58		
Eugenol-anethole-PEA			239		
Eugenol-anethole-PEB			78		138

Materials	9-1/3-1/3-1/3	7-1-1-1	2/3-2/3-8-2/3	1-7-1-1	1/3-9-1/3-1/3
Geraniol-eugenol-PEA-caproic	155	147			
Geraniol-eugenol-caproic-PEB			72		
Eugenol-anethole-PEA-caproic				126	137
Eugenol-anethole-caproic-PEB					136

Table XVII. Indices of beetles caught in 1948 when the attractive value of geraniol-eugenol (9-1) mixture is 100.

Materials	Proportions			
	9 - 1	8 - 2	2 - 8	1 - 9
Geraniol-eugenol		86	81	
Geraniol-PEA		84		
Eugenol-anethole				49
Eugenol-PEA	128	71		
	8-1-1	1-8-1	1-1-8	
Geraniol-eugenol-PEA	135	92	89	
Eugenol-anethole-PEA		81		

Table XVIII. Indices of beetles caught by individual materials.

Materials	Season					
	1943*	1944*	1946*	1947*	1949#	1949**
Geraniol	94		104	94	76	124
Eugenol	40		31	33	59	100
Anethole		39	22		9	15
Phenylethyl acetate			14		36	61
Caproic acid	11	30	14		22	38
Phenylethyl butyrate	38	54			22	38
Empty		7		16	12	21

**Standard in 1949 was eugenol with attractive value of 100

*Standard for other years was geraniol-eugenol (9-1) mixture with attractive value of 100

#Calculated with geraniol-eugenol(9-1) mixture having the attractive value of 100

Table XXII. Estimated costs of 40 gram baits of combinations of two materials.

Materials	Proportions						
	10 - 0	9 - 1	7 - 3	5 - 5	3 - 7	1 - 9	0 - 10
Geraniol-eugenol	$.180	$.182	$.186	$.190	$.194	$.198	$.200
Geraniol-anethole	.180	.170	.149	.128	.107	.086	.075
Geraniol-PEA	.180	.180	.179	.178	.177	.176	.175
Geraniol-caproic	.180	.176	.167	.158	.149	.140	.135
Geraniol-PEB	.180	.202	.246	.290	.334	.378	.400
Eugenol-PEA	.200	.198	.193	.188	.183	.178	.175
Eugenol-caproic	.200	.194	.181	.168	.155	.142	.135
Eugenol-PEB	.200	.220	.260	.300	.340	.380	.400

Table XXIII. Estimated costs of 40 gram baits of combinations of three materials.

Materials	Proportions						
	8-1-1	6-2-2	3'3'3'	2-6-2	2-2-6	1-8-1	1-1-8
Geraniol-eugenol-anethole	$.172	$.163	$.152	$.171	$.121	$.186	$.098
Geraniol-eugenol-PEA	.182	.183	.185	.191	.181	.196	.178
Geraniol-eugenol-caproic	.178	.175	.172	.183	.157	.192	.146
Geraniol-anethole-PEA	.169	.158	.143	.116	.156	.096	.166
Geraniol-PEA-caproic	.175	.170	.163	.168	.152	.172	.144
Geraniol-PEA-PEB	.202	.223	.251	.221	.311	.198	.356
Eugenol-anethole-PEA	.185	.170	.150	.120	.160	.098	.168
Eugenol-anethole-caproic	.181	.162	.137	.112	.136	.094	.136
Eugenol-PEA-caproic	.191	.182	.170	.172	.156	.174	.146
Eugenol-PEA-PEB	.218	.235	.258	.225	.315	.200	.358

Table XXIV. Estimated costs of 40 gram baits of

Materials	Proportions			
	7-1-1-1	1-7-1-1	1-1-7-1	1-1-1-7
Geraniol-eugenol-anethole-PEA	$.171	$.183	$.108	$.168
Geraniol-eugenol-anethole-caproic	.167	.179	.104	.140
Geraniol-eugenol-PEA-caproic	.177	.189	.174	.150
Geraniol-anethole-PEA-caproic	.165	.102	.174	.138
Geraniol-PEA-caproic-PEB	.197	.194	.170	.329
Eugenol-anethole-PEA-caproic	.179	.104	.164	.140
Eugenol-anethole-caproic-PEB	.201	.126	.162	.321

combinations of four materials.

2'2'2'2'	4-2-2-2	2-4-2-2	2-2-4-2	2-2-2-4
$.158	$.162	$.166	$.141	$.161
.148	.154	.158	.133	.145
.173	.174	.178	.173	.165
.142	.149	.128	.148	.140
.223	.214	.213	.205	.258
.147	.157	.132	.152	.144
.203	.202	.177	.189	.242

Table XXV. Ratio of costs to the attractive indices of the combinations of two materials.

Materials	Proportions						
	10-0	9-1	7-3	5-5	3-7	1-9	0-10
Geraniol-eugenol	145	111	129	133	146	149	200
Geraniol-anethole	108	163	183	183	237	390	341
Geraniol-PEA	120	84	92	146	227	241	357
Geraniol-caproic	155	90	128	99	106	226	375
Geraniol-PEB	105	158	384	137	281	232	1290
Eugenol-PEA	200	82	84	101	110	129	261
Eugenol-caproic	200	172	169	108	110	109	270
Eugenol-PEB	200	185	164	330	466	745	429

Table XXVI. Ratio of costs to the attractive indices of combinations of three materials.

Materials	Proportions						
	8-1-1	6-2-2	3'3'3'	2-6-2	2-2-6	1-8-1	1-1-8
Geraniol-eugenol-anethole	134	157	116	125	120	146	93
Geraniol-eugenol-PEA	62	65	60	57	62	61	91
Geraniol-eugenol-caproic	53	54	56	87	66	86	58
Geraniol-anethole-PEA	113	168	242	81	134	342	277
Geraniol-PEA-caproic	111	94	110	195	158	174	135
Geraniol-PEA-PEB	113	180	239	395	464	381	363
Eugenol-anethole-PEA	93	87	93	87	114	74	116
Eugenol-anethole-caproic	127	85	71	52	79	57	90
Eugenol-PEA-caproic	83	70	65	98	48	92	63
Eugenol-PEA-PEB	146	121	142	101	186	127	286

Table XXVII. Ratio of costs to attractive indices of

Materials	Proportions			
	7-1-1-1	1-7-1-1	1-1-7-1	1-1-1-7
Geraniol-eugenol-anethole-PEA	56	79	57	104
Geraniol-eugenol-anethole-caproic	86	81	47	73
Geraniol-eugenol-PEA-caproic	44	51	66	50
Geraniol-anethole-PEA-caproic	93	120	179	88
Geraniol-PEA-caproic-PEB	136	181	193	514
Eugenol-anethole-PEA-caproic	152	94	146	94
Eugenol-anethole-caproic-PEB	150	116	184	309

combinations of four materials.

2'2'2'2'	4-2-2-2	2-4-2-2	2-2-4-2	2-2-2-4
85	76	57	71	85
79	74	101	80	84
64	76	60	62	56
92	115	119	141	138
155	135	190	185	147
81	105	83	90	89
157	232	182	203	263

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