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FIELD EXPERIMENTS ON THE CHEMOTROPIC RESPONSES OF INSECTS.

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(With 1 Text-figure.)

PART I.

PRELIMINARY EXPERIMENTS.

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I. INTRODUCTORY REMARKS.

A SURVEY of the literature of applied entomology brings home the fact that the efforts of economic entomologists have been largely confined to the discovery of the means of destroying injurious insects; to studying their life-histories, and to ascertaining the most vulnerable stage thereof for the application of remedial measures. During the last few years artificial means for the destruction of noxious insects have progressed rapidly, and even the comparatively recent methods of combating them by the agencies of parasites have made remarkable advances. In all that has been achieved, however, it is evident that the scientific aspects of investigation have constantly been sacrificed in the interests of results derived by empirical methods. Insecticides are used throughout the

world and yet we scarcely possess any knowledge as to how they act. Since 1787, when the Abbe Roberjot first discovered the method of destroying the vine moth (*Sparganothis pilleriana*) by means of light, the application of this method has developed rapidly, and there are now in existence ingenious traps, elaborate lanterns and even expensive and complicated electric installations; but strange as it may seem, it was not until 1904 that the study of the effects of light of different colours, in attracting insects, was first taken up by Perraud. Even to this day our knowledge of the physical side of the subject is far from adequate; much research is also needed with regard to the influence of meteorological conditions, and we know comparatively little concerning the proportion of the sexes of the insects attracted. Chemotropism has shared no better fate, and we are largely in the dark as to the influence of the various constituents of those baits extensively used by economic entomologists. Molasses forms one of the most important ingredients, but we are totally ignorant as to which constituent (or constituents) of this complex substance exercises chemotropic properties. Dewitz (1912), Tragardh (1913) and Imms (1914) have emphasised the need for physiological research in applied entomology, but such research they insist must be carried on with a broader outlook than that of modern applied entomologists. The possibilities that the investigation of chemotropism offers, both as regards the application of results achieved and the advancement of scientific knowledge, can be well appreciated by reference to the work of Verschaffelt (1910), Howlett (1912, 1914, 1915), Barrows (1907), Richardson (1916, 1917) and others. There is hardly any doubt that one of the most promising aspects of applied entomology lies along these lines and, as will be pointed out on a later page, in chemotropism we should seek for new and effective measures for combating insect enemies. The control of the house-fly supports this contention, but we are only at the threshold of an extensive line of investigation.

The present paper only embodies observations of an essentially preliminary nature and were carried out by M. A. Husain at the suggestion of the senior author (A. D. Imms); the interpretation of the results and the writing of this article is a conjoint production. Delay has been inevitable in the preparation of this paper owing to one author being transferred to India, while the other was located at the Rothamsted Experimental Station, Harpenden. The necessary laboratory work was conducted in the Department of Agricultural Entomology, Manchester University. We are greatly indebted to Messrs C. G. Lamb, P. H. Grimshaw and H. Bury for help in identifying numerous specimens of Diptera.

II. GENERAL AND HISTORICAL.

Chemotropism is the response of an organism to the stimulus of chemical substances manifested, if the stimulus be responded to, in movements towards (positive chemotropism) or away (negative chemotropism) from the source of stimulus. Dewitz (1912) was the first to emphasise the importance of the study of tropisms in relation to applied entomology and dealt largely with phototropism. Tragardh (1913) laid stress upon chemotropism and pointed out possibilities of its application in combating destructive insects. There is no doubt that various tropisms play a vital part in the economy of insect life but, of these, chemotropism is the great controlling factor. The phenomenon is particularly evident in the search for food, in the pursuit of the sexes and the selection of suitable breeding places: it is also evident in many *apparently* unpurposeful responses. As Loeb remarks (1918), the Aristotelian point of view still prevails in biology namely, that an animal only moves for a purpose, either in connection with those functions just enumerated, or in relation to something else connected with the preservation of the individual or the race. In the words of this writer, "Science began when Galileo overthrew the Aristotelian mode of thought and introduced the method of quantitative experiments which leads to mathematical laws free from the metaphysical conception of purpose. The analysis of animal conduct only becomes scientific in so far as it drops the question of purpose and reduces the reactions of animals to quantitative laws." While admitting the justice of Loeb's remarks, we do not consider it desirable to eliminate all question of purpose from work of this nature, as the habits of a particular species not infrequently suggest the application of substances of chemotropic value, improbable to come under notice, except fortuitously, in other ways. Nevertheless, in many instances, it is remarkably difficult to prove that the observed facts bear the relation to a particular function which at first sight appears evident. The use of baits to attract insects was known to agriculturists of a hundred years ago, and when our forefathers found their land to be infested by wire worms they adopted the plan of burying beneath the soil slices of potatoes impaled on skewers (Weiss, 1912). These were examined frequently and the larvae which were attracted were collected and destroyed. One of the first important contributions to the scientific study of chemotropism, with reference to insects, is the work of Barrows (1907) who investigated the reactions of the pomace fly to odorous substances. This insect occurs in great numbers around cider-presses, packing sheds, orchards and other

situations where fermenting fruit is present; within the latter it deposits its eggs and its larvae develop. Barrows investigated the reactions of this fly to the various chemical constituents of fermenting fruit. Ethyl alcohol, acetic ether and acetic and lactic acids were experimented with separately, and in mixture. The insect was found to be attracted in the most marked degree by a mixture of ethyl alcohol of 20 per cent. strength and acetic acid of 5 per cent. It was further discovered that cider vinegar and fermented cider contain alcohol and acetic acid in percentages very close to those just quoted. A series of experiments were conducted proving that the fly discovers its food by means of the olfactory sense, the latter being located in the terminal joint of the antennae. In 1908, Forbes experimented with various reagents with reference to the Corn Root Aphis, with the object of discovering substances towards which this species reacts negatively. The seeds were treated with various chemicals of which carbolic acid, formalin, kerosene and oil of lemon were found to be of value as repellants, aphid attacks being noticeably reduced after the seeds had been thus dealt with. In 1910 Verschaffelt published an important and highly suggestive paper, embodying his investigations of the factors which determine the selection of food in the case of the larvae of *Pieris brassicae* and *P. rapae*. The larvae select as their food plants certain Cruciferae, also *Tropaeolum* and *Reseda*. In these plants there occurs a group of glucosides—the mustard oils. Verschaffelt took a solution of sinigrin, which constitutes the glucose agent in black mustard, and uniformly distributed it over the leaves of plants which the *Pieris* larvae had previously refused to eat. Leaves so treated were devoured readily. From such experiments it appears that the *Pieris* larvae exhibit a marked chemotropism towards mustard oils, and it is due to their presence in the leaves of certain plants that determines the selection of the latter by the larvae for their food. By a similar method of research, Verschaffelt has shown that the larvae of the saw-fly, *Prionophorus (Cladius) padi*, which feed on certain of the Rosaceae, are attracted by the glucoside known as amygdaline. As regards those factors which determine the females to select certain species of plants for purposes of oviposition, definite information might be acquired by carrying out an analogous series of experiments. In 1911 Patterson observed that flies (Sarcophagidae) would not oviposit on freshly killed material (caterpillars) in the cages even though the females had been ovipositing previously on older decomposing caterpillars. This would tend to show that the material must reach a certain stage of decomposition before the female would oviposit. In 1912 Howlett published some

observations dealing with the reactions of certain Indian fruit flies. He found that citronella oil exercises a remarkable attraction for the males of *Dacus diversus* and *D. zonatus*, and suggested that possibly this reagent is allied to a secretion emitted by the females, and that the phenomenon of the only being attracted is to be regarded as a reproduction, by artificial means, of a sexual attraction similar in kind to that which operates in most cases of "assembling." In a later paper (1915), Howlett conducted a further series of experiments, confirming his previous results that certain odours are remarkably attractive to male flies of the genus *Dacus* and, that by the employment of attractive substances, the movements of the flies can to a great extent be controlled in any given direction. Three of the common species (*D. diversus*, *ferrugineus* and *zonatus*) normally breed respectively in (1) anthers of Cucurbitaceae, (2) fruits of Solanaceae and mango, and (3) peach, guava, mango and other fruits. *D. diversus* (1) is most strongly attracted by iso-eugenol, *zonatus* by methyl-eugenol, and *ferrugineus* (2) by both iso- and methyl-eugenol. The odours of these substances have not yet been identified with those of the plants which constitute the normal breeding-places, but male flies have been found attracted to mango, Papaya, a Cycad and *Colocasia*, plants with a very characteristic smell similar to that of eugenol-derivatives. Females have never been seen to frequent these plants or to breed in them, but more extended observation on this point is needed. Three explanations suggest themselves. (a) That the smell is a direct sexual guiding smell, emitted by the female as previously suggested, but the young crushed females do not attract males. (b) The smell is not emitted by the female, but may be termed an "indirect" sexual guide to the plants where the females are accustomed to congregate for breeding purposes. Under these circumstances it is difficult to see why females should not be attracted by the odoriferous chemicals. (c) The odour is a food smell; if this be so it can only be attractive to males. It is evident that further critical research is greatly needed eliminating, at any rate for the time being, the metaphysical conception of purpose. In a third paper Howlett (1914) noted the marked response of Thrips to the stimulus of the odours of benzaldehyde, cinnamylaldehyde and anisaldehyde. In his earlier paper (1912), Howlett conducted a further series of experiments with regard to the influence of reagents upon oviposition and it appears not unlikely that the odours of chemical substances provide the required stimulus. Thus, he found *Sarcophaga* to be very strongly attracted to a flask containing a solution of skatol, a substance normally present in faeces and many larvae were

deposited therein. *Stomoxys calcitrans* was also induced to oviposit on cotton wool soaked with valerianic acid—a substance occurring in decaying vegetable refuse. Howlett further adds that both valerianic and butyric acids have a similar attraction for an Ortalid fly of the genus *Ulidia* (?) in India. H. H. P. and H. C. Severin (1913–15, 1918) have made a series of studies on the attraction of kerosene for the Mediterranean fruit fly, *Ceratitis capitata*. Enormous numbers of this species have been trapped by the agency of kerosene in various parts of the world, but the number of females attracted is negligible. This species is also attracted by crude petroleum, naphtha distillate, gasolene, etc., all mineral oils that do not normally occur in the environment of the species. Chatterjee (1915) in India has discovered that kusum oil (oil from *Schleicheria trijuga*) has a marked attraction for both sexes of the Coreid bug *Serinetia augur* Fabr., and also for the nymphs in all stages. Dean (1915) has discussed the value of poisoned bran mash flavoured with orange or lemon juice and distributed over areas infested with grasshoppers, army worms, cut worms, etc. In each case the chemotropic value of the mixture was greatly enhanced by the addition of orange or lemon. According to Simpson (1918) tsetse flies are attracted by oil of cloves, essence of orange and essence of lemon. In Queensland, Jarvis (1916) has found that the cane beetle (*Lepidiotia albobirta*) is not influenced by the oils of plants allied to its food plant, but is attracted by cajeput oil, acetic acid, carbolic acid, nitrobenzene, and especially oil of almonds. We have, therefore, numerous instances of responses towards substances which do not occur in the normal surroundings of an insect.

The chemotropic responses of the house-fly have been more extensively investigated than those of any other insect. Thus Morrill in 1914 conducted a series of experiments with a variety of substances some of them of great chemical complexity, and varying very much in their chemotropic properties. Among others vinegar and beer (under certain conditions) were both found to be markedly attractive; formalin varied exceedingly. Commercial alcohol (95 per cent.) 1 pint, and water 20 pints, was found to be more attractive after the addition of sugar. The addition of bread to alcohol and alcohol mixtures increased their attractive properties, and also those of various other substances. Commercial dried blood, moistened with water, was found to have an attractive value greater than fresh and decomposed meat and fish. Cane syrup, and sugar and water, were found to have relatively low attractive values when used without other materials. Buck (1915) conducted somewhat similar experiments and found that not less than 3 per cent. nor more than 8 per

cent. of 95 per cent. ethyl alcohol in water was a good attractive agent. Sucrose was found to be a valuable addition to various baits, sometimes increasing their attractive properties 10–20 per cent. According to Richardson (1916) the female house-fly is strongly attracted towards manure for purposes of oviposition, food being only a secondary object. He exposed a number of liquids and found that ammonium carbonate was the most attractive. Small amounts of water and carbon dioxide, both constituents of ammonium carbonate, were not sought after by the flies, and it was concluded that the other constituent, ammonia, was the real attracting agent. Of the flies attracted only 7.6 per cent. were males. His experiments indicated that manure which was liberating ammonia was more attractive than fresh manure. Richardson was successful in inducing oviposition on a mixture of moist Timothy chaff and ammonium carbonate, whereas the chaff alone produced no result. In experiments conducted with moist sterilised absorbent cotton, ammonium carbonate exercised practically no chemotropic stimulus for oviposition, but was effective when traces of butyric acid were added: valerianic acid was attractive to a lesser degree. Crumb and Lyon (1917) investigated the question more fully, and produced evidence suggesting that carbon dioxide is the chief stimulant for oviposition, giving an 82 per cent. higher stimulus than ammonia. Richardson (1916) conducted some further experiments with reference to the attraction of Diptera to ammonia and found that it attracted various species. Those which respond to this stimulus are known to spend at least part of their lives in some form of animal excrement. The response is not always a simple one as was shown in his earlier investigation. In this same paper Richardson remarks that he was unable to induce *Stomoxys calcitrans* to oviposit on cotton wool soaked in valerianic acid, although Howlett was successful with this experiment in India. In 1917 Richardson conducted a series of tests with reference to the house-fly, using a wide range of substances placed in fly traps. A number of carbohydrates were tested in solution and, on the whole, they did not prove very attractive: lactose attracted the largest number of flies and starch the least. Dextrin also caught a comparatively large number of flies, but sucrose was consistently a poor attractive agent. In using alcohols and acids he found that 4 per cent. amylic alcohol gave better results than ethyl alcohol. Ethyl alcohol in 4 per cent. strength was more attractive than in 10 per cent. concentration; 10 per cent. acetic acid gave better results than 4 per cent. Succinic and lactic acids exhibited some attractive qualities in two experiments. Maltose, lactose, sucrose and dextrin in 4 per cent. solutions of amylic alcohol, ethyl

alcohol and acetic acid were found more attractive than the aqueous solutions of these substances. Crude gluten from wheat flour was not attractive. The water soluble portion, with or without starch in suspension, was decidedly attractive. Several experiments with milk indicated that fat-free caseinogen is attractive while butter fat is not. In 1918 Miss Lodge published a paper on the sense-reactions of flies—mainly those species likely to be concerned with the spread of intestinal diseases. The experiments were conducted indoors, and the different substances were tested both upon free flies and those confined in glass cylinders provided with muslin tops. The authoress states that the most suitable medium for the experimental tests was found to be equal parts of casein, sugar and banana, to which a solution of the substance to be tested was added. In all cases, therefore, an extraordinarily complex chemotropic substance was utilised, to which was added various other chemical agents of varying complexity. The results showed that, although many of the substances attracted a certain number of Diptera present in the room, yet none were so attractive that all the flies went to them. Pyrethrum extract, added to the medium already described, proved very attractive to *Calliphora*, ammonia proved attractive to *Phormia azurea*, ammonia and honey to *Musca domestica*; the latter insect was also attracted by honey and methylene blue, 1 per cent. nicotine, ammonium carbonate, and other substances. The addition of an aqueous solution of skatol was attractive to *Calliphora* and *Scatophaga*; camphor attracted *Calliphora* and also honey, the latter substance was attractive also to *Lucilia caesar*. As a control the casein mixture was adopted and this substance proved more attractive to *Calliphora* and *Lucilia* than any other reagent when added to it. Mineral and tar oils proved to be powerful repellents, the essential oils were, on the whole, repellents. Davidson (1918) states that 12 per cent. glycerine and 5 per cent. sugar to which was added 1 per cent. sodium arsenite proved a successful poisonous attractive agent for flies during the Egyptian campaign of the late war. Parker (1918) found a combination of beer and oatmeal proved a most attractive substance for the females of various Diptera frequenting privy vaults in Montana.

In the foregoing summary of the literature bearing upon Chemotropism we have included the more important papers but it makes no pretence of being exhaustive. A further object of this resume is to emphasise the fact that no systematic quantitative work has yet been attempted, and most of the observations so far recorded concern particular species only. A large number of chemical substances are sufficiently volatile to merit adequate trials, and it is our intention during these

researches to examine as many as possible, recording the species which respond, irrespective of whether they are injurious or otherwise. We are of opinion that quantitative work of this kind will provide a broader basis for a scientific understanding of the problems involved, than specialised experiments conducted for the purpose of combating any particular species of injurious insect.

III. METHODS.

Experimental researches upon chemotropism divide themselves into two groups—those conducted under the more or less artificial conditions of an enclosed room, and those carried out under field conditions. It is scarcely necessary to add that preliminary experiments in any branch of physiology need to be carried out under definitely known and controllable conditions of temperature, light, humidity, air currents, etc., and in such a way as to eliminate as many of these factors as may be desired. Such simplified conditions are scarcely possible in researches of the nature under consideration, except in the case of experiments conducted indoors. Our present researches are entirely concerned with field experiments, and we are firmly of the opinion that preliminary indoor trials are of little value in this connection. Insects reared and liberated under artificial conditions, and surrounded by a totally alien environment, do not necessarily react in a manner similar to those living free in their natural habitat. In the case of insects concerned with the spread of disease, and normally frequenting dwellings, hospitals, etc., these remarks naturally do not apply, and their reactions form no part of our observations.

Chemotropic work in the field presents innumerable difficulties and in no line of biological research with which we are acquainted is there so large a number of environmental and other factors to be taken into consideration. Success or failure of any chemotropic experiment depends primarily upon the presence of favourable atmospheric conditions. One is therefore largely at the mercy of climatic influences, which, in a country like England, are extremely variable. Temperature, air-currents, humidity, etc. have a direct bearing upon the evaporation of the substances to be tested, and the dissemination of their odours. Furthermore, atmospheric changes influence the tropisms of insects to a marked degree. Degree of temperature and amount of sunshine affect their activities, a dull cloudy day may inhibit their movements very noticeably, a strong wind interferes with flight, and excess of moisture inhibits their activities in other directions. There are also many unknown factors which exercise

their influence in different ways: the time of day, season, degree of development of the gonads, age of the insects concerned, state of hunger, development of the eggs, whether oviposition is in progress or not, all probably have a definite bearing upon the chemotropic responses of insects, but we are totally in the dark as to how they manifest themselves. We have observed, and also Richardson (1917), that the same attractive substance may vary in effectiveness on different days under apparently similar atmospheric conditions. This may be due to one or other of the above-mentioned factors, or depend upon the actual number of insects present in a given locality at a particular time, or may in some way be correlated with sex attraction. Feytaud in his experiments in trapping moths discovered that some traps lured exceptionally large numbers, especially at the end of the season, and in some cases in the proportion of only two females to 54 males. He attributes this to sex attraction, females being trapped first, males subsequently following them. In view of the complexity of the factors which have to be taken into account, it is necessary to repeat every individual experiment a number of times during the season, and keep very full meteorological data. It will consequently be evident that reliable results, concerning the chemotropic properties of even a small number of substances, take several years to achieve.

All experiments to have any scientific value must be checked by a definite control. When a chemical agent is exposed, and it attracts certain insects, we acquire definite data. The question then to be gone into is its relative attractive value as compared with other substances. To prove that any substance exhibits attractive properties we are faced with a number of problems. The negative results do not necessarily imply that the agent has no attractive value, as the species which may respond to the stimulus may be absent from the immediate locality at a given time. It is, therefore, necessary to devise a double control—one to prove that certain species of insects are actually present at the place and time of observation, and the other to show that the substance being dealt with has, or has not, chemotropic properties. As mentioned above, water may serve as one control, but to devise the second control substance is less easy of achievement. It is necessary to use a substance known to exhibit powerful chemotropic properties and this, in itself, is liable to vitiate the experiment in attracting insects which might have otherwise responded to the substance required to be tested. The senses of insects are very acute, and minute traces of a reagent are known to produce marked results. We are also totally ignorant as to the distance

which the odour of a particular substance may exercise chemotropic properties. According to Howlett (1915) the radius of attraction of citronella oil for certain fruit flies may be taken as about half a mile: with many Lepidoptera the female probably attracts the male from a much greater distance. It is evident, therefore, we should guard against placing substances to be tested too near to each other. For every agent to be tested suitable controls have to be decided upon, and spaced as far apart as may be possible.

In our field experiments we have to obtain the following data:

- (1) Power of attraction of a substance in various dilutions and under varied atmospheric conditions.
- (2) Optimum attractive strength.
- (3) Relative powers of attraction as compared with other substances.
- (4) The species attracted, their numbers and the proportion of the sexes.
- (5) Meteorological data.

There are two methods of discovering substances likely to exhibit chemotropic attraction. The one is to undertake experiments with any substance that normally occurs in the environment of particular species, e.g. a constituent of the food of the larvae or adult, or likely substances chemically allied to the same. The second method is to test a large number of substances, necessarily somewhat indiscriminately at first, in the hope of discovering attractive agents. Verschaffelt (1910) observed that the alkaloid that gives mustard oil is the attractive agent in the larval food of *Pieris brassicae*; he started with the food plants and worked with the ingredients thereof. Richardson, who has studied the reactions of the house-fly to various agents, also followed this same method. He first observed that the house-fly is attracted to the manure heap by the odour of certain substances, which were being liberated during the early stages of fermentation. On this basis, he experimented with various inorganic and organic compounds that occur in the manure heap. This method is full of possibilities, in so far as individual species are concerned, but the second of the above methods has its advantages for preliminary quantitative work. It has been observed that a large number of insects are attracted towards chemicals that are neither associated with the smell of their food substances, nor occur in their normal environment. It is, moreover, in the discovery of such substances that some of the most striking results have so far been achieved. We have therefore followed this method of exposing a large number of chemicals and

recording the results. So far as possible we have worked with simpler substances, leaving the more complex organic compounds for later work. It is hoped that by this method it will be possible to discover whether any general relationship exists between chemical constitution and attractive properties.

The question of a suitable trap for exposing the agents used is of very great importance. It is essential that the substances to be tested should be exposed in traps so constructed as to admit any insects that are attracted thereto and, at the same time, preclude their escape. A free outlet for the uniform dispersal of the odour of each reagent used is essential and, furthermore, the constructional materials must be inodorous, and must not be readily acted upon by chemicals. Convenience of size and handling should not be overlooked, and the traps should be readily washable whenever necessary. After trials with various types of traps it was found that one based upon the Minnesota model (Washburn, 1912) was more suitable than any other. It possesses, however, the defect that insects can only enter around the base of the trap, and it is extremely likely that a certain number of insects which may be attracted do not succeed in entering. We have mainly used a rectangular trap of this type measuring 11" x 7" x 9" covered with ordinary fine white muslin, which can be readily renewed when necessary. The colour or condition of the trap appears to exercise some influence in the attraction of insects. Thus Dewitz (1912) states that white saucers are more attractive than coloured ones. Morrill (1914) also observed that insects came more readily to a new balloon trap than to a rusty trap. During trials conducted with clean empty traps, however, we found that the number of insects which entered therein was negligible. The greatest number was five Diptera and one Lepidopteron, after 36 hours exposure. In each experiment 50 c.c. of a chemical substance of a known strength was exposed for a given time, and full details recorded of any species attracted. It proved difficult during these preliminary trials to keep full meteorological data but, as far as possible, a record of maximum and minimum temperatures, both by means of ordinary and wet and dry bulb thermometers, was kept and the general conditions of the weather noted.

During one trial an empty trap was exposed on one occasion and we were surprised to find a considerable number of Diptera entrapped. On the previous day this same trap contained a markedly attractive agent and many insects were caught. It appears, therefore, evident that either the odour of the previous reagent lingers, and still exercises chemo-

tropic properties or, possibly, some smell is emitted by the flies themselves and their faeces, and serves to attract further individuals. The importance of using perfectly clean traps is thus rendered particularly important. The traps were suspended from trees and posts at a height of 2-4 feet from the ground. Owing to the junior author (Husain) having at his

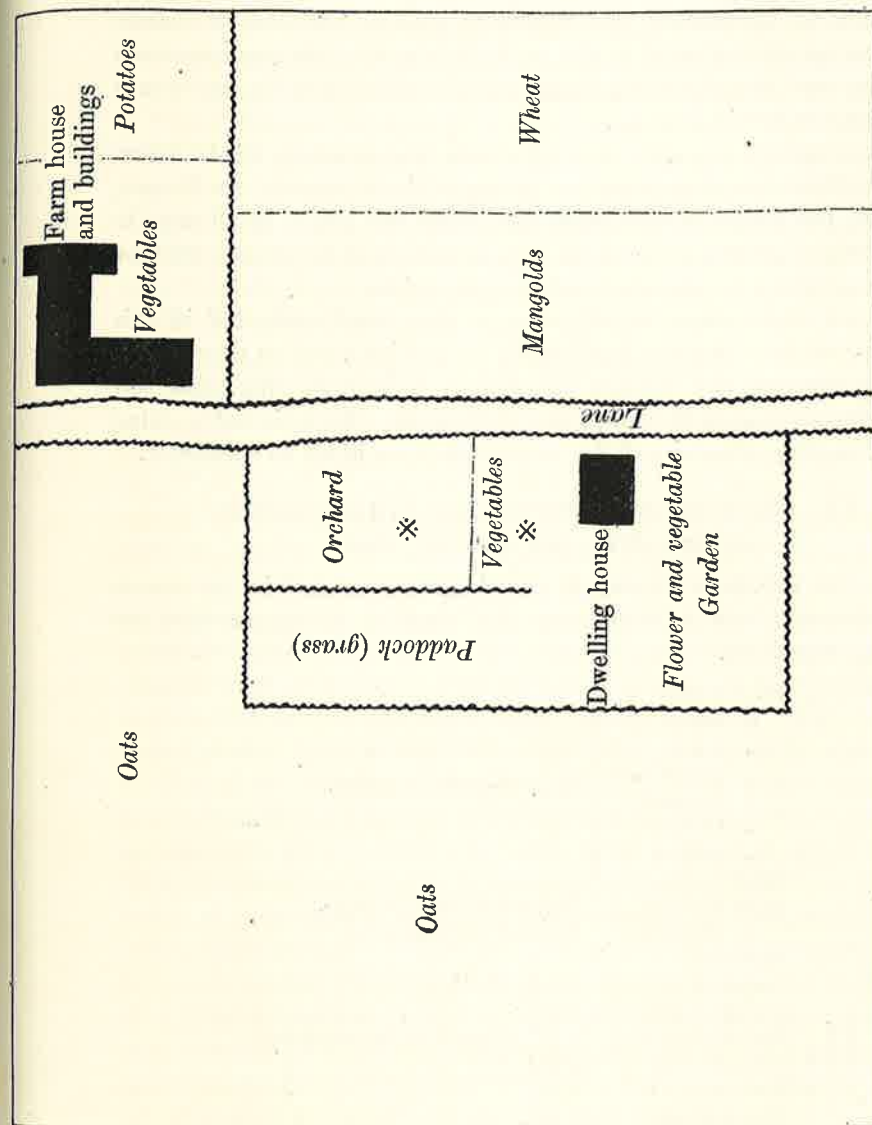


Fig. A. Somewhat diagrammatic sketch-plan showing the immediate surroundings of the areas where the experiments were conducted.

disposal the short period of only 10 weeks wherein to conduct these experiments, they can only be regarded as essentially preliminary in nature. War conditions also added to the difficulty in procuring certain reagents, and the summer of 1918 proved to be one of the wettest for a number of years. During the months of July–September there was scarcely more than two clear sunny weeks. Our observations were conducted at Lymm (Cheshire) in an orchard and vegetable garden, and the immediate surroundings are indicated in Fig. A. Less than 60 yards away are farm buildings and accompanying manure heaps which provide sustenance for great numbers of Diptera.

The length of exposure of a substance was generally 24–48 hours, but sometimes longer or shorter according to circumstances. Mr Husain, however, has not given very exact data upon this point. In all cases in which long exposures were resorted to, it was owing to adverse weather conditions which necessitated more lengthy trials.

As our observations are the first of their kind conducted in this country, we have deemed it advisable to publish them as they stand, without drawing any definite conclusions therefrom. We have laid particular stress upon the difficulties of the work, with a view of warning other intending observers of the pit-falls they are likely to encounter.

IV. OBSERVATIONS CONDUCTED AT LYMM (CHESHIRE) DURING JULY AND AUGUST, 1918.

(1) The following substances gave negative results, *i.e.* no insects were attracted, and it is probable that some of the agents used are powerful repellents.

Aqueous solutions, 50 c.c.	Oil of cajeput		} Exposed on two occasions.
	,, orange		
	,, lemon		
	,, sandal wood		
	,, bergamot		
	,, cloves		
	,, juniper		}
	Birch tar oil		
	Oil of aniseed		Exposed on three occasions.
	,, citronella		Exposed on six occasions.
	Menthol		} Exposed on two occasions.
	Turpeniol		
Potassium hydroxide (5%)			
Hydrochloric acid (5%)			
Sulphuric acid (5%)			
Malic acid (5%)			
Benzaldehyde (5%)			

All the oils enumerated above were used both in wire balloon traps and the Minnesota model traps. In one series of experiments a few drops were allowed to fall on blotting paper and placed in the usual receptacle within the traps. In a second series of experiments, an approximately similar quantity of each oil was added to 50 c.c. of water and shaken to form an emulsion.

(2) *Kerosene*. This substance is known abroad to attract insects belonging to such diverse groups as aphids, mosquitos, barklice, moths, cockroaches, Syrphid flies, Coccinellidae and their larvae, also a number of Tachinidae and parasitic Hymenoptera (Severin, H. H. P. and H. C., 1915). In our experiments it was exposed on four occasions: during one exposure it attracted a number of Nematocera, but on the remaining occasions the results were negative. It is important, however, to recognise that the kerosene used in these trials probably differed in composition from that employed in America.

(3) *Vinegar*. The records were as follows:

Aug. 19–30.	40 c.c. vinegar	100 c.c. water	22 Diptera
Aug. 30–31.	25 c.c. "	50 c.c. "	3 "
	10 c.c. "	50 c.c. "	1 " and 1 <i>Vespa vulgaris</i>
	5 c.c. "	50 c.c. "	2 "
Aug. 31.	40 c.c. "	100 c.c. "	5 "

(4) *Ethyl alcohol*. Ethyl alcohol (approximately 95 per cent. strength) was used in the following percentages, 36, 22.5, 12.5, 10, 7, 5, 3, 2.5, 1, .7, .4, and .2. These solutions (50 c.c.) were used both as controls for other experiments and as independent chemotropic agents, but no attractive properties were evident in any instance. Our experiments with solutions stronger than 36 per cent. were vitiated, and need to be repeated. The 5 per cent. solution attracted eight Diptera and this result was only achieved after 48 hours exposure. Our results are somewhat remarkable in view of the fact that Richardson (1917), in New Jersey, caught 891 examples of *Musca domestica* in the course of six experiments, representing an aggregate of 207 hours exposure, using 4 per cent. ethyl alcohol. This observer found that a 10 per cent. solution, exposed in the same series of experiments, attracted 544 examples of that same species, which made up more than 95 per cent. of the Diptera attracted during the whole course of his trials. The latter were conducted within 50 yards of a prolific breeding ground of the insect, and our own experiments were carried out within 60 yards of farm accumulations of manure, and decaying organic matter of various kinds. Buck (1915), also in America, observed that not less than 3 per cent. and not more than 8 per cent. of 95 per cent. ethyl alcohol was a markedly attractive agent.

(5) *Glacial acetic acid*. Glacial acetic acid was not observed to exercise any marked chemotropic attraction as the following experiments indicate.

Aug. 27-29.	50 c.c. water	5 c.c. glacial acetic acid	1 Dipteron
" 21-23.	" "	1 c.c. "	Nil
" 21-22.	" "	.5 c.c. "	3 Diptera
" 24-27.	" "	.5 c.c. "	13 "
" 27-29.	" "	.5 c.c. "	12 "
" 24-27.	" "	.1 c.c. "	2 "

(6) *Ethyl alcohol and glacial acetic acid*. Unlike either of these substances, when used separately, a mixture of the two was found to be markedly attractive. Ethyl alcohol and acetic acid when brought into contact form small quantities of ethyl acetate and, as shown in Barrow's experiments (1907), ethyl acetate exercises a marked attraction for *Drosophila ampelophila*. The amount of ethyl acetate formed by using such small quantities of the two substances as 1 per cent. of ethyl alcohol and 0.05 c.c. of acetic acid under outdoor conditions must be very small. In each experiment 50 c.c. of ethyl alcohol or water was used.

Exp. 1.	Aug. 19-21.	10% ethyl alcohol + 1 c.c. glacial acetic acid	69 Diptera
" 2.	" 21-23.	10% " + 1 c.c. " "	0 (control)
" 3.	" 21-22.	10% ethyl alcohol + .5 c.c. " "	329 Diptera
" 4.	" 22-23.	10% ethyl alcohol + .5 c.c. " "	0 (control)
" 5.	" 22-23.	10% " " " "	82 Diptera
" 6.	" 27-29.	5% " + .5 c.c. " "	3 (control)
" 7.	" 22-23.	5% " + .2 c.c. " "	12 Diptera
" 8.	" 23-24.	5% " + .1 c.c. " "	2 (control)
" 9.	" 23-24.	5% " + .05 c.c. " "	41 Diptera
" 10.	" 23-24.	2.5% " + .5 c.c. " "	2 (control)
" 11.	" 23-24.	2.5% " + .1 c.c. " "	214 Diptera
" 12.	" 23-24.	2.5% " + .05 c.c. " "	8 (control)
" 12a.	" 23-24.	2.5% " " " "	14 Diptera
" 13.	" 24-27.	1% " + .5 c.c. " "	7 "
" 14.	" 24-27.	1% " + .05 c.c. " "	10 "
" 15a.	" 24-27.	1% " " " "	25 "
" 14.	" 24-27.	1% " + .1 c.c. " "	12 "
" 14a.	" 24-27.	1% " + .1 c.c. " "	4 "
" 14a.	" 24-27.	water + .1 c.c. " "	1 (control)
" 13.	" 24-27.	1% " + .5 c.c. " "	122 Diptera
" 15.	" 24-27.	1% " + .05 c.c. " "	45 "
" 15a.	" 24-27.	1% " " " "	0 (control)
" 14.	" 24-27.	1% " + .1 c.c. " "	19 Diptera
" 14a.	" 24-27.	water + .1 c.c. " "	2 (control)

It appears evident, therefore, that the greatest attractive properties are exercised when at least .5 c.c. acetic acid is present, and they are enhanced by an increased strength of the alcohol. Experiments with greater strengths than 10 per cent. ethyl alcohol were unable to be carried out, owing to adverse weather conditions.

		Experiment nos.																
Totals	2	3	4	6	7	8	9	10	11	12	13	14	15	16	17			
183	123	1	—	18	1	—	—	—	—	—	2	—	—	8	30	<i>Rhyphus</i>		
4*	—	—	—	—	—	—	—	—	—	—	—	—	—	2*	2*	<i>punctatus</i>		
65	42	1	—	7	1	1	—	—	—	—	—	—	—	4	9			
1*	—	1*	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>Rhyphus</i>		
1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>fenestralis</i>		
25	7	5	—	4	—	—	—	—	—	—	1	—	1	—	7	<i>Onesia</i>		
34	4	2	—	4	—	—	—	—	1	—	4	1	—	—	18	<i>sepulchralis</i>		
47	11	10	3	3	—	—	1	1	—	—	4	—	1	1	12	<i>Sarcophaga</i>		
18	—	4	—	1	—	—	—	1	1	—	2	—	—	1	8	<i>carnaria</i>		
8	—	—	—	2	—	—	—	—	—	—	1	—	—	1	4	<i>Pollenia</i>		
1*	—	—	—	—	—	—	—	—	—	—	—	—	1*	—	—	<i>rudis</i>		
6	—	—	—	1	—	—	—	—	—	—	1	—	—	—	4			
3	—	—	—	2	—	—	—	—	—	—	—	—	1	—	—	<i>Graphomyia</i>		
1.	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	<i>maculata</i>		
17	4	2	—	6	1	—	—	—	—	—	—	—	—	—	4	<i>Muscina</i>		
10	2	2	—	2	—	—	—	—	—	—	—	—	—	—	4	<i>stabulans</i>		
5	2	—	—	—	—	—	—	—	—	—	—	—	—	3	—	<i>Muscina</i>		
1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>caesia</i>		
6	2	1	—	1	—	—	—	—	—	—	—	—	1	—	1	<i>Muscina</i>		
8	4	—	—	2	—	—	—	—	—	—	—	—	—	—	2	<i>pabulorum</i>		
16	—	4	1	5	—	—	1	—	1	1	2	—	—	—	1	<i>Mesembrina</i>		
3	—	—	—	—	—	—	—	—	—	—	1	—	—	—	—	<i>meridiana</i>		
71	12	3	—	14	—	—	—	3	1	—	6	1	1	10	20	<i>Calliphora</i>		
44	6	2	—	14	—	—	3	—	—	—	3	—	1	7	8	<i>erythrocephala</i>		
56	9	3	—	17	—	—	—	—	—	—	—	1	3	2	21	<i>Calliphora</i>		
64	7	1	—	16	—	—	—	1	—	—	—	—	3	2	30	<i>vomitaria</i>		
75	19	6	—	16	—	—	—	—	—	—	1	1	2	8	22	<i>Lucilia</i> sp.		
61	19	3	—	14	—	—	—	—	—	—	2	1	—	4	18			
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>Mydaea</i>		
18	1	2	—	1	—	—	2	2	—	—	3	—	—	2	5	<i>impuncta</i>		
4	—	—	—	1	—	—	—	—	—	—	—	—	—	—	3	<i>Spilogaster</i>		
5	—	—	—	1	—	—	—	—	—	—	—	—	—	—	4	<i>duplicata</i>		
1	—	—	—	1	—	—	—	—	—	—	—	—	—	—	—	<i>Hydrotaea</i>		
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>dentipes</i>		
110	4	4	1	15	4	—	2	3	—	—	14	3	3	25	32	<i>Hylemyia</i>		
243	6	6	5	24	7	4	—	14	7	3	36	9	11	53	58	<i>strigosa</i>		
2	1	—	—	—	—	—	—	—	—	—	1	—	—	—	—	<i>Hytodesia</i>		
—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>errans</i>		
1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>Anthomyia</i>		
2	1	—	—	—	—	—	—	—	—	—	—	—	—	—	1	<i>pluvialis</i>		
24	6	2	1	2	—	—	—	—	—	—	2	1	—	—	10	<i>Fannia</i>		
1	1	—	—	—	—	—	—	—	—	—	—	—	—	—	—	<i>canalicularis</i>		
6	—	1	—	1	—	—	—	—	—	—	1	—	1	1	1	<i>Scatophaga</i>		
5	—	—	—	1	—	—	—	—	—	—	—	—	—	1	3	<i>stercoraria</i>		
208*	34*	14*	2*	17*	—	2*	1*	—	1	—	30*	1*	15*	69*	22*	Unidentified, mostly Anthomyidae		
1466	329	82	13	214	14	7	10	25	12	4	121	19	45	204	365	Totals		

On Aug. 24-29 (Exp. 17) two vessels were placed closely together in the same trap: one contained 50 c.c. of 5 per cent. ethyl alcohol, and the other 50 c.c. of 1 per cent. glacial acetic acid. The vapours of the two solutions coming in contact would produce very minute quantities of ethyl acetate. This, however, proved to possess powerful attractive properties, 365 Diptera pertaining to various species being entrapped. In another experiment (No. 16) (Aug. 24-27), 50 c.c. 2 per cent. glacial acetic acid was used, and the same quantity of 10 per cent. ethyl alcohol was placed in a second vessel as before, and 204 Diptera were attracted during 42 hours exposure. The question arises whether it is the vapour of the ethyl acetate that is alone responsible for this attraction, or the mixed vapours of the ethyl alcohol, acetic acid and ethyl acetate that produced the effect. This problem is at present unanswered. As a control on the same days (Aug. 27-29) 5 per cent. ethyl alcohol attracted only eight Diptera.

An analysis of the species attracted and the number of each sex obtained is given on p. 285. The numbers at the head of each column refer to those allotted to each of the foregoing experiments. The figures opposite each species refer to the number of individuals attracted, the upper figures representing males and the lower figures females: figures bearing * are cases in which the sexes of the individuals were not determined.

7. *Ethyl acetate*. We have so far only conducted a few experiments with this ester. From Aug. 2-8 an emulsion of 10 c.c. of ethyl acetate in 50 c.c. of water attracted only 39 Diptera. From Aug. 8-12 a mixture of 5 c.c. ethyl acetate and 50 c.c. of a 25 per cent. solution of cane molasses proved attractive. During the same period a trap containing 25 c.c. of beer in place of the ethyl acetate attracted 108 examples of various Diptera.

8. *Methyl acetate*.

Aug. 12-14. 5 c.c. water + 10 c.c. methyl acetate. 3 Diptera.

" 15-16. 5 c.c. 10% ethyl alcohol + a few drops of methyl acetate. 11 Diptera.

9. *Amylic acetate*. On Aug. 16-19 an emulsion consisting of 33 per cent. amylic acetate in water attracted seven Diptera: with 20 per cent. amylic acetate six Diptera were attracted, and with 9 per cent. acetate 10 Diptera responded.

(10) *Butyric and valerianic acids*. Normal butyric acid in water exhibited no attractive properties, but traces of this substance in ethyl alcohol proved very attractive, this property probably being due to the ethyl butyrate formed. Iso-butyric acid gave less satisfactory results.

Traces of valerianic acid in ethyl alcohol is also an attractive mixture. The experiments were as follows:

1.	Aug. 15-16.	10% ethyl alcohol	+ traces of butyric acid	39	Diptera
"	" 16-19.	Water	+ " "	3	"
2.	" 21-22.	10% ethyl alcohol	+ 5 c.c. butyric acid	82	"
"	" "	Water	+ 5 c.c. "	2	"
3.	" 22-24.	10% ethyl alcohol	+ 5 c.c. "	20	"
4.	" "	10% "	+ 5 c.c. iso-butyric acid	7	"
"	" "	10% "	— — —	2	"
5.	" 15-16.	10% "	+ traces of valerianic acid	37	"

The species attracted were as follows: an * indicates that the sex was undetermined.

Exp. 1	Exp. 2	Exp. 5	Species attracted
1♂	2♂	—	<i>Sarcophaga carnaria</i>
—	1♀	—	<i>Pollenia rudis</i>
1♂	—	—	<i>Musca domestica</i>
1♂	2♂	—	} <i>Calliphora erythrocephala</i>
1♀	—	—	
—	3♂	—	<i>C. vomitoria</i>
—	—	1♂	<i>Mesembrina meridiana</i>
3♀	2♀	1♀	<i>Mydaea impuncta</i>
—	—	1♀	<i>Spilogaster duplicata</i>
1♀	2♀	—	<i>Muscina stabulans</i>
—	1♂	—	} <i>M. caesia</i>
—	1♀	—	
—	—	1♂	} <i>M. pascuorum</i>
—	1♀	—	
10♂	—	5♂	} <i>Hylemyia strigosa</i>
13♀	2♀	8♀	
4♂	1♂	1♂	<i>Fannia canalicularis</i>
4*	64*	19*	Unidentified, mostly Anthomyidae
39	82	37	Totals

(11) *Beer*. Beer has long been known to exercise marked chemotropic properties. It forms an important constituent of a number of baits used on a practical scale, for the purpose of attracting and trapping injurious Lepidoptera. Our observations confirm the high attractive properties of this substance, and we have also been able to definitely prove that it is equally, or even more, attractive in so far as Diptera are concerned. Beer is a complex chemical substance, whose composition varies in almost every sample, and it is essential to ascertain which constituent or constituents exercises this power. Our researches are now being conducted with this object in view.

The following experiments were performed for the purpose of testing the relative value of 50 per cent. solutions of beer and a mixture of beer

and cane molasses—the latter itself being an important attractive agent. Two small American balloon traps were fitted up for the purpose and were suspended close together from the same tree. The one trap A was charged with 60 c.c. beer solution and the other trap B was charged with 30 c.c. undiluted beer and 30 c.c. of a 25 per cent. solution of cane molasses, with the following results. July 13–14. Trap A, 11 flies; B, 11 flies. July 14–16. A, 4 flies; B, 57 flies. July 16–19. A, 5 flies; B, 65 flies. It was observed that Diptera responded much more quickly to the stimulus of beer, but the latter speedily lost its attractive properties. After the second day, probably on account of the fermentation which was going on in the molasses mixture, trap B became far more attractive. On July 6–8, 200 c.c. of a 50 per cent. solution of beer in a Minnesota trap attracted 928 Diptera, the largest number recorded in any of our experiments. On July 11–13 a 33 per cent. solution of beer attracted 175 Diptera. The species attracted are recorded below, the figures in brackets referring to the weaker solution. *Scatopse* sp. 11*. *Rhyphus punctatus* Fab. 98♂, 60♀, 27* (5♂, 2♀). *R. fenestralis* Scop. 2♀. *Onesia sepulchralis* L. 20♂, 12♀ (4♂, 6♀). *Sarcophaga carnaria* L. 2♂, 6♀ (5♂, 1♀). *Pollenia rudis* Fab. 8♂ (2♂, 5♀). *Muscina stabulans* Fall. 1♂. *Morellia hortorum* Fall. 1♂, 1♀. *Mesembrina meridiana* L. 8♂, 3♀ (2♂). *Pyrellia eriophthalma* Macq. 8♂, 10♀ (1♀). *Calliphora erythrocephala* Mg. 29♂, 24♀ (3♂). *C. vomitoria* L. 6♂, 3♀ (1♀). *Euphoria* sp. 1♀. *Lucilia* sp. 12♂, 8♀. *Mydaea mediatunda* F. 4♂, 1♀ (1♂, 2♀). *M. impuncta* Fall. 23♂, 11♀ (6♂). *Spilogaster duplicata* Mg. 3♀. *S. pubescens* Stein. 3♂. *S. demigrans* Ztt. (1♂). *Hydrotaea dentipes* Fab. 7♂, 1♀ (1*). *Hylemyia strigosa* Fab. 92♂, 30♀ (37♂, 44♀). *Polietes lardaria* Fab. 3♂, 8♀ (1♂). *Hytodesia marmorata* Ztt. 2♀. *Anthomyia pluvialis* L. 1♀. *Fannia canalicularis* L. 7♂ (2♂). *F. manicata* Mg. 1♂. *Fannia* sp. 17♂, 5*. *Scatophaga stercoraria* L. 16♂, 2♀ (5♂, 10♀). *Themira putris* L. 1♂. *T. minor* Hal. 1♂, 7♀. *Drosophila obscura* Fall. 2*. *Dolichopus griseipennis* Stan., *Piophilus vulgaris*, *P. nigriceps* Mg., a few examples of each were attracted by the 50 per cent. solution and many examples of a species of *Sciara* and *Sepsis*. *Helomyza* sp., a few examples were attracted by both solutions. Unidentified Diptera (mostly Anthomyidae) 300 (32).

(12) *Cane molasses*. The variety used was that commonly known as "black treacle"—an extremely complex substance of variable chemical composition. Our researches have not so far included an investigation of the attractive agents present, but it is intended to pursue this line of research at the earliest opportunity. Cane molasses (50 c.c.) was used

in 25 per cent. and 50 per cent. solutions in distilled water, both alone, and with the addition of certain other substances as detailed below.

July 4–5.	50% solution	...	...	...	...	256 Diptera
" 8–12.	25% "	...	...	...	...	36 "
" "	25% "	+	(50 c.c.)	25 c.c. beer	108	"
" "	25% "	+	5 c.c. 10% ammonia		8	"
" "	25% "	+	5 c.c. 10% malic acid		12	"
" "	25% "	+	5 c.c. 5% acetic acid		4	"
" "	25% "	+	5 c.c. ethyl acetate		2	"

It is evident from these results that cane molasses in strong solution is an extremely attractive substance. When used in 25 per cent. solution its chemotropic properties are increased by the addition of beer, but in these experiments the addition of the other substances quoted above had no positive effect.

Species attracted.—50 per cent. solution. *Rhyphus punctatus* Fab. 48♂, 21♀. *Onesia sepulchralis* L. 15♂, 8♀. *Sarcophaga carnaria* L. 2♂. *Pollenia rudis* Fab. 5♂, 4♀. *Muscina (Cyrtoneura) stabulans* Fall. 1♂, 1♀. *M. pabulorum* Fall. 3♀. *Morellia hortorum* Fall. 1♂. *Pyrellia eriophthalma* Macq. 1♂, 4♀. *Phormia* sp. 1♂. *Calliphora erythrocephala* Mg. 3♂, 1♀. *Mydaea mediatunda* F. 2♂, 2♀. *M. impuncta* Fall. 11♂. *Spilogaster duplicata* Mg. 5♂. *S. pubescens* Stein. 1♂. *Hydrotaea dentipes* Fab. 2♂, 2♀. *Hylemyia strigosa* Fab. 29♂, 13♀. *Polietes lardaria* Fab. 5♂, 7♀. *Hytodesia errans* Mg. 1♂. *Chortophila trichodactyla* Rond. 1♂. *Fannia* sp. 11♂, 9♀. *Scatophaga stercoraria* L. 2♂, 1♀. *Helomyza* sp., *Themira putris* L., *T. minor* Hal., *Sepsis* sp., *Sciara* sp., a few examples of each Unidentified Diptera, mostly Anthomyidae 30.

25 per cent. solution + 25 c.c. beer.—*Rhyphus punctatus* Fab. 21♂, 12♀, 2 sex not determined. *Onesia sepulchralis* L. 5♂. *Sarcophaga carnaria* L. 1♂, 1♀. *Pollenia rudis* Fab. 1♂. *Muscina stabulans* Fall. 1♂, 1♀. *Calliphora erythrocephala* Mg. 21♂, 12♀. *C. vomitoria* L. 2♂, 1♀. *Euphoria* sp. 1♀. *Lucilia* sp. 16♂, 7♀. *Polietes lardaria* Fab. 1♂. *Hytodesia errans* Mg. 1♀. *Anthomyia pluvialis* L. 1♂, 1♀. *Themira putris* L., *T. minor*, *Sepsis* sp., *Sciara* sp., a few examples.

We do not regard it likely to be of much value, at present, to publish the meteorological records kept in these preliminary experiments. The trials were not conducted on a sufficiently extensive scale to warrant any conclusions being drawn, with reference to the relations between weather conditions and insect behaviour. Furthermore, owing to the war we were unable to procure the necessary self-recording instruments. Without the aid of the latter, the data provided by the ordinary wet and dry

bulb thermometer, for example, are of little comparative value, and could not be obtained during the night. The most noteworthy features of the experiments enumerated in the preceding pages may be summarised as follows.

1. The experiments were conducted during July and August 1918, and for the most part during wet and apparently unfavourable climatic conditions.

2. The insects attracted consisted almost exclusively of Diptera. With the exception of one or two examples of *Vespa vulgaris*, no Hymenoptera responded. Rhynchota, Coleoptera and Neuroptera (*sen. lat.*) were unrepresented. A small number of Noctuid Lepidoptera entered the traps, but for the purpose of conducting experiments with such relatively large insects, as many Lepidoptera, it would be necessary to slightly alter the construction of the traps used in order to allow of greater facilities for ingress.

3. Beer, cane molasses, and mixtures of these two substances are powerful chemotropic agents for various Diptera. Ethyl alcohol, in various concentrations, exhibited little or no chemotropic properties but with the addition of small amounts of butyric, valerianic or acetic acids it exercised a powerful stimulus. Aqueous solutions of the above acids were not attractive, the respective esters probably being the attractive agents in each case. The remaining substances utilised in these experiments were found to exhibit little or no positive chemotropic properties.

4. Out of considerably over 3000 Diptera attracted during the course of these observations, by far the greater number pertained to one or other of the five families Rhyphidae, Mycetophilidae, Sepsidae, Muscidae and Anthomyidae.

5. As a general rule members of both sexes of a species were attracted irrespective of the chemotropic agent employed. In the majority of instances males predominated over females, but in no case where the number of individuals of a species attracted exceeded 20 was the proportion greater than 2.9 males to 1 female.

6. *Rhyphus punctatus*, *Hylemyia strigosa* and *Calliphora erythrocephala* were the dominant species attracted.

V. BIBLIOGRAPHY.

- BARROWS, W. M. (1907). The Reactions of the Pomace Fly (*Drosophila ampelophila*) to odorous substances. *Journ. Exp. Zool.*, iv., pp. 515-37.
- BUCK, J. E. (1915). Fly Baits. *Circ. 32, Alabama Agric. Expt. Sta.*
- CHATTERJEE, N. C. (1915). Chemotropism; influence of Kusum oil on Insects. *Journ. Bombay Nat. Hist. Soc.*, pp. 198-99.
- CRUMB, S. E. and LYON, S. C. (1917). The effects of certain chemicals upon oviposition in the House-fly. *Journ. Econ. Entom.*, x., p. 532-36.
- DAVIDSON, J. (1918). Some practical Methods adopted for the Control of Flies in the Egyptian Campaign. *Bull. Entom. Res.*, viii., pp. 297-309.
- DEAN, G. A. (1915). Further Data on Poisoned Bran Mash flavoured with Fruit Juice as a means of controlling some Insects. *Journ. Econ. Entom.*, viii., pp. 219-27.
- DEWITZ, J. (1912). The bearing of Physiology on Economic Entomology. *Bull. Entom. Res.*, iii., pp. 343-54.
- FEYTAUD, J. and BOS, J. (1914). Observations sur l'emploi des pièges-appâts contre Eudémis. *Bull. Soc. Et. Vulg. Zool. Agric.*, Bordeaux, xiii., pp. 30-34 and 45-50.
- (1914). La lutte contre la mouche de l'olivier en Italie. *Bull. bi-mens. Gov. Gén. Algerie*, xx., pp. 98-100.
- FORBES, S. A. (1908). Experiments with repellents against the Corn Root Aphis. *Journ. Econ. Entom.*, i., pp. 81-83.
- HOWLETT, F. M. (1912). The effects of oil of citronella on two species of *Dacus*. *Trans. Entom. Soc.*, pp. 412-18.
- (1914). A Trap for Thrips. *Journ. Econ. Biol.*, ix., pp. 21-23.
- (1915). Chemical reactions of Fruit Flies. *Bull. Entom. Res.*, vi., pp. 297-306.
- IMMS, A. D. (1914). The Scope and Aims of Applied Biology. *Parasitology*, vii., pp. 69-87.
- JARVIS, E. (1916). Combating the Cane Beetle. *Queensland Agric. Journ.*, v., pp. 169-70.
- LODGE, O. C. (1916). Fly Investigations Reports. 4. *Proc. Zool. Soc.*, pp. 481-518.
- (1918). An Examination of the Sense Reactions of Flies. *Bull. Entom. Res.*, ix., pp. 141-51.
- LOEB, J. (1918). *Forced Movements, Tropisms and Animal Conduct.*
- LUTCHNIK, V. (1914). Note on trapping insect pests. Reprint from *Friend of Nature*, published by the Section of Agric. and Exp. Organization of Kiev Soc. of Agric. and Agric. Industry. (Vide *Rev. App. Entom.*, 1914, A, p. 138.)
- MOREAU, L. and VINET, E. (1913). Au sujet de l'emploi des pièges à vin pour capturer des papillons de la Cochylis. *C. R. Acad. Sci. Paris*, clvii., pp. 1158-60.
- MORRILL, A. W. (1914). Expérimentations with House-fly Baits and Poisons. *Journ. Econ. Entom.*, vii., pp. 268-74.
- PARKER, R. R. (1918). Data concerning Flies that frequent privy vaults in Montana. *Entom. News*, xxix., pp. 143-46.
- RICHARDSON, C. H. (1916). A Chemotropic Response of the House Fly. *Science*, xliii., pp. 631-16.
- (1916). The Attraction of Diptera to Ammonia. *Ann. Ent. Soc. America*, ix., pp. 408-13.
- Ann. Biol. vi

- RICHARDSON, C. H. (1917). The Response of the House-fly to certain Foods and their Fermentation products. *Journ. Econ. Entom.*, x., pp. 102-109.
- SEVERIN, H. H. P. and H. C. (1913). An historical account of the use of Kerosene to trap the Mediterranean Fruit-fly. *Journ. Econ. Entom.*, vi., pp. 347-51.
- (1914). The Behaviour of the Mediterranean Fruit-fly towards Kerosene. *Jl. Anim. Behav.*, iv., pp. 223-27.
- (1914). Relative Attractiveness of vegetable, animal and petroleum oils for the Mediterranean Fruit-fly. *Journ. N. Y. Entom. Soc.*, xxii., pp. 240-48.
- (1915). Kerosene Traps as a means of checking up the effectiveness of a Poisoned Bait Spray to control the American Fruit-fly. *Journ. Econ. Entom.*, viii., pp. 329-38.
- SEVERIN, H. H. P. (1918). Oils tested to trap Trypetidae and Ortalidae. *Journ. Bull. Calif. State Comm. Hortic., Sacramento*, vii.
- SIMPSON, J. J. (1918). Bionomics of Tsetse and other Parasitological notes from the Gold Coast. *Bull. Entom. Res.*, viii., p. 206.
- TRAGARDH, I. (1913). On the chemotropism of Insects and its significance for Economic Entomology. *Bull. Entom. Res.*, iv., pp. 112-17.
- TRYON, H. (1916). Bean Flies and other pests. *Queensland Agric. Jl.*, vi., pp. 34-35.
- VERSCHAFFELT, E. (1910). The cause determining the selection of food in some herbivorous Insects. *Amsterdam Vers. Wis. Nat. Afd. K. Akad. Wet.*, xix., pp. 594-600 (Dutch); *Proc. Sci. K. Akad. Wet.*, xiii., pp. 536-542 (English).
- WASHBURN, F. L. (1912). The Minnesota Fly Trap. *Journ. Econ. Entom.*, v., pp. 400-402.
- WEISS, H. B. (1912). Some economic methods a hundred years old. *Journ. Econ. Entom.*, v., p. 88.

ON FORMS OF THE HOP (*HUMULUS LUPULUS* L. AND *H. AMERICANUS* NUTT.) RESISTANT TO MILDEW (*SPHAEROTHECA HUMULI* (DC.) BURR.).

IV.

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In previous articles⁽¹⁾⁽²⁾⁽³⁾ it has been pointed out that resistance to the attacks of the mildew *Sphaerotheca Humuli* (DC.) Burr. is found in certain forms of *Humulus Lupulus* L., viz., (1) in a variety known to nurserymen as the "Golden Hop," and (2) in certain seedlings of the wild plant obtained from Italy. Experiments have now demonstrated the existence of a form of *H. americanus* Nutt. resistant to mildew. Our present knowledge with respect to these three groups of mildew-resistant hops is given below.

(1) THE "GOLDEN HOP."

Several distinct forms of *H. Lupulus* with yellow ("golden") leaves are on sale by nurserymen. These forms are quite distinct, and in several instances the stocks in nurseries have become mixed. The following information has been collected with respect to the characteristics, origin and name of these forms.

(1) Plants were obtained under the name of "Golden Hop" from Messrs Bunyard and from Messrs Bide and Son. In both cases the stock proved to be mixed, the plant sent being sometimes female and immune, and sometimes male and fully susceptible to mildew. Mr E. A. Bunyard has written to me: "I fancy our 'Golden Hop' came from Messrs Bide and Son, but no record was kept." Messrs Bide and Son wrote, in March, 1916: "We bought the plants in the first place from M. G. Bénard, Orleans, France. We do not claim to be the introducers of this plant, as we quite think it is to be had from other firms in this country." In Feb. 1918, Mr A. R. Bide wrote: "I cannot tell you definitely how many years we have listed this, but it is certainly 8 to 10. I first saw this growing in the nursery of Messrs Turbat et Cie, when I was at Orleans, and as I had never seen the Golden variety before, I bought some. Since