Frank Milburn Howlett (1877–1920): discoverer of the Pied Piper's lure for the fruit flies (Tephritidae: Diptera)

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Hundred years after the fascinating discovery of a male tephritid lure by Imperial entomologist Frank Milburn Howlett in 1912, methyl eugenol reigns today as the most important surveillance and male annihilation tool for several Bactrocera species all over the world. Unfortunately the discoverer, Howlett did not receive enough recognition compared to his peers of yester era. Even 100 years after its discovery, no other sex or food lure can match the strong potency of methyl eugenol when it comes to attracting tephritids into traps, leaving an unexplained huge gap and challenge for tephritid chemical ecologists.

How often have we discarded a luscious mango or a fleshy guava, just because we found a maggot or two squirming through the pulp though the exterior was seemingly good? This is one true case of deceptive looks. The cause: a fly of family Tephritidae which breeds in fruits. World over, the plague due to fruit flies, a group known as tephritids (three to four times the size of a drosophillid), has literally sunk the fruit trade and exports. Fortunately with the advent of a 'Pied-Piper chemical', these flies are lured away from the fruit into a magic box – a trap indeed – where they live (or rather die) forever. This 'Pied-Piper chemical' saved the orchard industry billions of dollars every year. It is now a century since the Pied Piper's lure (PPL) was discovered. Known in chemical jargon as methyl eugenol (ME) it attracts the male tephritid fruit flies – a discovery that has immensely helped in eradicating invasive flies in several parts of the globe, and helped in trapping pestilent flies that attack several fruits.

Yet, among all the Imperial entomologists of early last century, the name of the discoverer of PPL, Frank Milburn Howlett (in spite of authors' search, no record of his photograph is available in any of the known entomological archives, including Pusa collections at New Delhi) is less heard compared to his contemporaries like E. L. Distant, A. Forel, E. H. Aitken, H. M. Lefroy, G. F. Hampson, C. T. Bingham, E. P. Stebbing, A. A. J. Rothnay, T. B. Fletcher and so on. Though most of these Englishmen have helped lay a strong foundation for Indian entomology, Howlett's contribution – the discovery of ME as an attractant for males of several *Bactrocera* (*Dacus*) species (Tephritidae: Diptera) – as early as 1912 somehow got mired in the pages of history (Figure 1). As the most potent tool in surveillance, monitoring and male annihilation of several species of tephritids world over, ME gained more prominence and can be ranked among the most researched and used of all parapheromones. That the discovery of ME originated from India (Pusa) in the early part of the last century is yet another aspect that has escaped proper acknowledgement.

Inexplicably, from discovery to application of ME in fruit fly monitoring and management, took more than 50 years. Today, a century after its discovery, ME traps are commercially available to control *Bactrocera dorsalis* (Hendel), *B. zonata*, *B. correcta*, etc. on mango, guava, anona, etc. in India[1], and several other tephritid species, on an array of fruits world over. One of the earlier successes which caught great attention with ME was the eradication of *B. dorsalis* from the Island of Rota[2]. In the late seventies, use of ME enabled reduction of infestation of *B. zonata* below economic levels in Pakistan[3]. In India, the ball was set rolling for use of ME in male annihilation, integrated with sanitation and baits to achieve high levels of control, thanks to a joint research effort by the Indian Council of Agricultural Research and Imperial College London, DFID, UK[4]. Use of ME traps is rapidly becoming popular across India and already lakhs of mango acreage in southern Gujarat, Karnataka, Tamil Nadu, Kerala, Maharashtra, Uttar Pradesh and Andhra Pradesh has been adopting the ME traps (Figure 2). Further, Indian Institute of Horticultural Research has developed a novel technology to impregnate ME into plywood blocks, and commercialization of this technology has been already given to eight licensees. It has to be underlined here that it took nearly 90 years since Howlett's discovery for the commercialization of this technology.

History of the discovery of Pied Piper's chemical

It all started with the observation of Howlett (1912) that oil of citronella (a non-host) attracts male fruit flies of *Bactrocera* (Dacinae, Tephritidae). Howlett's (1912–1915) meticulous experiments first established that oil of citronella attracted three species of fruit flies *Dacus* (= *Bactrocera*) *zonatus*, *D*(*B*) *ferrugineus* (= *B. dorsalis*) and *D. diversus*. His application of mind and astute ability to deduce with systematic experimentation (actually a form of bioassay) by sheer trial and reasoning were the hallmarks of his research. The approach to the study clearly brought out his knowledge in chemistry and high acumen of a qualitative biologist of those days. His keen observational prowess coupled with deductive reasoning established facts, even without a statistical treatise, and laboratory chemical analysis. But, he hit the nail on the head when he zeroed in on ME as the source to which the male flies got lured[5] and for this he deserves all acclaim.

The same study today would have been through a series of statistically designed experiments, chromatography, and may be even sophisticated wind tunnels to validate olfaction. Such a combination of approaches may not have been the order of the day of research done early last century.

Howlett's name is sometimes quoted along with methyl eugenol as lure[6] for the sheer significance of his discovery in fruit fly and surveillance. However, the significance of the discovery from India often goes almost unmentioned. Probably today's generation fails to connect English names with a past colonial India. Nevertheless, the former Imperial Agricultural Institute of Pusa, Bihar (now

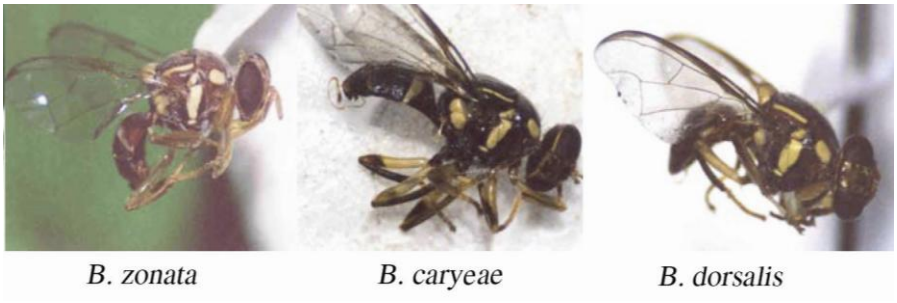

Figure 1. Major tephritid fruit flies that are attracted to methyl eugenol.

Figure 2. Different types of traps being used all over the world for monitoring and controlling tephritids using methyl eugenol as lure: ***a***, McPhail trap; ***b***, IIHR trap; ***c***, Low-cost IIHR trap; ***d***, Steiner trap; ***e***, Delta trap; ***f***, Live fruit-fly catch trap.

Indian Agricultural Research Institute, New Delhi) should be hailed for this research contribution, the fallout of which ramified across the globe. Many administrators of the Imperial era, doubled as biologists or life scientists. Their love and acumen for nature led them to many biological and species discoveries. In fact, Howlett's statement says it vividly: 'I was unable to get analyses of the citronella used, and relied at first on a partially correct statement that the main constituents of the oil were citronellal, atral, citronellal and geraniol. All these were tried many times, both alone and mixed in various combinations and proportions but none had any attraction whatever'[7]. Obviously, he had conducted several experiments using these constituents with a negative result.

It was in the March of 1913, that Howlett 'had the good fortune' of obtaining Thorpe's (1911) edition of '*Dictionary of Applied Chemistry*'[8]. According to Howlett, this publication had more accurate information regarding the constituents of oil of citronella.

According to Thorpe, components of oil of citronella were geraniol, citronellal, camphene, dipentene, limonene, with small amount of linalol, borneol, ME, methyl heptenone and sesquiterpenes. He also had through this publication, access to constituents of other oils. Armed with the information, Howlett again carefully conducted a series of experiments which had single and combination of mixtures of all the above constituents which helped in eliminating constituents one by one, till he hit on ME as a sure source of attraction. He then concluded thus: 'Now the previous experiments had shown quite clearly that the attraction of citronella was not diminished by admixture with other substances of a more or less similar character, and I felt justified therefore in ruling out of consideration all the constituents in the above list which also occurred in reasonable quantity in any of the oils which I had previously found unattractive. These were as follows: Geraniol, citronellal, camphene, dipentene, limonene, linalool, borneol and methyl heptenone. That is to say, out of the list given by Thorpe, the only definite constituent of citronella which had not been tested in the series of trials of different oils was methyl eugenol.'[7]

Next, Howlett procured the synthetic form of ME from Messrs Merck, and

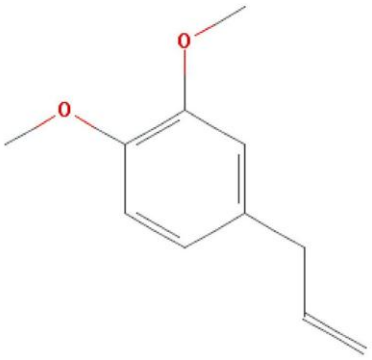

Figure 3. Two-dimensional chemical structure of methyl eugenol also known as eugenol methyl ether, *O*-methyleugenol, 4-allyl-1, 2-dimethoxybenzene, 4-allylveratrole, 93-15-2, 3,4 dimethoxy-allylbenzene ($C_{11}H_{14}O_2$; molecular weight: 178.22766).

evaluated and obtained catches of males of *D.* (*B*) *zonatus* and *D.* (*B*) *ferrugineus* (Figure 3). He could now establish that ME was an attractant for these dacine flies – a finding from India which revolutionized management and eradication of both pestilent and invasive fruit flies globally.

Now, as all the flies attracted to the lures were males, Howlett was naturally inclined to think it was a sex attractant. But being an observant biologist and scientific in inferring, he exposed crushed females in the same manner as ME, but found no males attracted to it. So he concluded: 'If the smell is not a direct sexual guide, it might be (a) a food-smell; involving the assumption that the feeding habits of the males are quite different from those of the females; (b) a "rendezvous" smell, guiding males to the eugenol-derivative-producing plants on which the females were accustomed to rest; involving the assumption that the females decided on their resting-places for other reasons.'[8]

Subsequent experiments have confirmed overwhelmingly that ME is essentially a food attractant for males[9] and is found in several plants, the most common being *Ocimum* species[10].

This article places on record the wide application of ME as a male lure of tephritids, and global ramification of an Indian discovery a century ago. The general loss due to fruit flies to fruit industry is several hundred million dollars[11]. This discovery has saved such huge loss and has contributed to the upliftment of several fruit growers all over the world. What was foretold about this discovery in an obituary on Howlett published in *Nature* (1920), seemed so prophetically true; to quote '… His studies of the chemotropic responses of various Diptera attracted very wide attention, and subsequent research has demonstrated that they were the forerunners of a line of investigation which has a promising future.' The credit goes to its discoverer, the late F. M. Howlett, who in his short span of 43 years, rendered yeoman service, first as a chemist and then as an entomologist. At the time of his death in 1920 in Pusa, his designation was unique – 'Imperial pathological entomologist'[13].

Hang a trap with the Pied Piper's lure in any backyard and a trail of male flies stream into it, much the same way as rats, nay, the children of Hamelin followed the Pied Piper into the mountains[14].

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