性費洛蒙在蟲害管理上之應用與發展

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摘　要

近年由於微量化學分析技術的進步，發現很多天然或合成的化學物質與昆蟲的行爲、生理、族群組成、生殖、及生存息息相關，這些物質通常與生物同種或不同種個體間訊息之傳遞有關，故總稱爲化學傳訊素（Semiochemicals），此類物質主要可改變昆蟲的行爲，故又稱爲 Behavior-modifying chemicals(BMCs)，包括費洛蒙（Pheromone）、開洛蒙（Kairomone）、阿洛蒙（Allomone）、新洛蒙（Synomone）及阿紐蒙（Apneumone）等。其中以性費洛蒙又稱性誘引劑之利用最爲普遍。由於性費洛蒙一般具很強的生物活性、用量少、專一性高、持久性長、無毒性、與其他蟲害防治措施（尤其是生物防治）相容性大、及一般實驗室即可產製等特性，因此，性費洛蒙被視爲合乎環保條件的生理性防治劑(Biorational pesticide)之一。至今約有一千多種昆蟲的費洛蒙或引誘劑被分離、鑑定及合成，數百種的費洛蒙被廣泛應用在蟲害管理計畫中，性費洛蒙及其類似物之應用方式主要爲：(1)偵測法或監測法，(2)大量誘殺法，(3)交配干擾法或迷惑法，(4)其他利用方式，包括被利用來監測田間抗藥性昆蟲的發生，輔助蟲種鑑定，作爲研究害蟲遷移分散行爲工具，性費洛蒙兼具開洛蒙者可增強天敵利用效率，及施用做成陷阱作物(Crop trapping)以減少農藥施用範圍及藥量等。性費洛蒙之研發與應用是屬高科技，須多種學門的研究人員長期通力合作始有所成。展望未來，臺灣性費洛蒙之研發與應用工作，宜包括：(1)本土主要作物重要害蟲性費洛蒙組成分之分離與鑑定，(2)性費洛蒙簡易大量合成方法之研發，(3)生物檢定技術及性費洛蒙配方之研究，(4)誘捕系統之設計，(5)經濟效益評估，(6)推廣教育等。希望在有志之士共同努力研究之下，性費洛蒙及其類似物在台灣的蟲害管理體系中，未來能扮演更重要的角色，提供更適切、成功的利用途逕，以促進殺蟲劑更合理的使用，並確保生態環境的品質。

（關鍵詞：性費洛蒙、蟲害管理、台灣）

緒　言

根據世界糧農組織(FAO)估計，全世界農作物的生產，每年因為有害生物的侵害，可造成約 35 % 的產量損失，僅蟲害一項的產量損失約 14 % (Metcalf, 1970)。因此化學殺蟲劑長期被大量使用來防治蟲害的發生，雖然保護了農作物免於害蟲的侵害，但也衍生了許多不良的副作用，諸如：抗藥性害蟲的增加，傷害非標的生物及天敵，促使主要害蟲重覆發生及次要害蟲容易猖獗；而有些殺蟲劑具長效性及生物蓄積性，更容易帶來破壞生態平衡、減低生物多樣性、環境污染等問題，及農藥殘留毒害人體健康等後遺症(Bottrell, 1979；Metcalf, 1970)。

現今世界農業生產的新潮流是有機農法的永續農業理念，而永續農業的植物保護趨勢是害物綜合管理(Integrated Pest management , IPM)，各國的專家學者已公認害物綜合管理及許多替代性的防治方法，是唯一可減少傳統農藥使用的策略(Anonymous, 1988；Dent, 1991; Huang *et al*., 1993；Shani, 1990)。Gonzalez(1970)即認為發展一個蟲害綜合防治計劃，就如建造一棟樓房(圖一)，應建基於：害蟲的取樣調查、害蟲的經濟防治基準、害蟲族群的自然死亡因子(族群動態)；而蟲害防治的技術，就如樑柱一樣，包括：抗蟲品種、生物防治、耕作防治、誘引及忌避劑利用、物理防治、不孕技術、遺傳操縱、法規防治、殺蟲劑的使用等多種方法。亦即希望透過對害物的生物及生態學之充份了解，以保育天敵及發展各種害蟲防治技術，聯合運用來抑制害蟲的發生，並促進傳統殺蟲劑的合理使用，以降低殺蟲劑在環境的負載量及不良的副作用。

早在 17、18 世紀，博物學家即發現自然界中的生物，尤其是昆蟲個體之間，或與其寄主植物、天敵之間，彼此藉著某些化學物質(化學語言)來互通訊息。近年來，由於微量化學分析技術的進步，科學家們已分離、鑑定出許多天然的化學刺激物質（Chemical-releasing stimuli ），這些物質與昆蟲的生理、行為、族群組成、生殖及生存息息相關，其可被分為二大類(圖二)：一是體內的激素或賀爾蒙（Hormone），另一為生物體間的化學傳訊素（Semiochemicals）。化學傳訊素又可分為二類：一是不同種間的傳訊素，稱為"異體作用素(Allelochemicals)，其中對分泌者有益而對接受者有害的稱為"阿洛蒙"(Allomone, 或利己素)；對分泌者有害而對接受者有益的稱為"開洛蒙"(Kairomone, 或利他素)；對分泌者與接受者雙方均有益的則稱為"新洛蒙"(Synomone，或互利素)；非生物性的化學物質而對接受者有益的稱為阿紐蒙(Apneumone)。另一為同種生物之間的傳訊素，稱為費洛蒙(Pheromone)(Nordlund *et al*., 1981；Stine, 1986)。Dethier *et al*.（1960）曾依化學刺激物質對昆蟲引發的行為反應型式，

而將前述各種化學刺激物質分類為：誘引劑（Attractant）、忌避劑（Repellent）、阻礙劑（Arrestant）、刺激劑（Stimulant）及抑制劑（Deterrent）等類(Metcalf & Luckman, 1975)。

由於這些可改變昆蟲行為的化學物質(Behavior-modifying chemicals, BMCs)，很不同於傳統的殺蟲劑(表一)，一般具有很強的生物活性、用量少、專一性高、持久性長、無毒性、與其他蟲害防治措施（尤其是生物防治）相容性大、及合成容易不需複雜設備與空間，一般實驗室即可產製等特性，因此，如何研發利用各種行為改變化學物質(BMCs)，尤其是具有誘引作用的性費洛蒙（Sex pheromone〉，來協助解決蟲害問題，乃是世界各國諸多學者專家極力發展的各種生理性防治劑（Biorational pesticides）之一。

費洛蒙研究與發展歷程

早在三百多年前生物學家就知道昆蟲會利用嗅覺氣味來傳遞消息，例如：1609 年歐洲人 Charles Butler 在其論文"The Feminine Monarchie"中提到"…尤其在大熱天，一隻蜜蜂螫了人後，其它蜜蜂會聞到螫針的氣味而群集攻擊人們…"(in Davidson, 1985)。1878 年法國博物學家 Fabre 在其著作"昆蟲記"裡寫著:大孔雀蛾夜裡會飛越過山谷河川，找到異性來交配以繁衍後代。 但一直到 1959 年德國化學家 Butenandt *et al.*歷經 30 餘年的研究，始自五十萬隻雌性家蠶腹部腺體內，首次分離出 12 mg 純化結晶的雌性誘引物質，並鑑定出其化學結構為（E）10-(Z)12-hexadecadien-1-ol(簡稱家蠶醇 Bombykol)，並創議此類物質稱為 Pheromone(音譯為費洛蒙)(Karlson & Butenandt, 1959)，彼等亦因此而獲得諾貝爾化學獎。至 1966 年美國 Berger 才再分離並鑑定出第二種昆蟲的性費洛蒙，其自二千五百隻甘藍擬尺蠖(Cabbage looper)分離出 5 mg 的誘引物質，並鑑定為(Z)-7-dodecenyl acetate (Berger, 1966)。

Pheromone 一詞語源自希臘文的 pherein 及 hormon，分別有傳遞(to transfer)及興奮或刺激(to excite)之意思(Karlson＆Butenandt, 1959)。費洛蒙最早的定義是"生物成熟個體分泌出體外的物質，可被同種其他個體接收，而引發某些特殊的反應，包括特定的行為或發育過程"(Karlson & Luscher, 1959)。按照費洛蒙所引發的行為反應或生物功能，通常可將昆蟲費洛蒙分別為四類：(1)性費洛蒙(Sex pheromone)：昆蟲為了達到有效交配與生殖以繁衍後代之目的而分泌者，如甘藷蟻象、桔柑粉介殼蟲、亞洲玉米螟及斜紋夜蛾等之性費洛蒙。(2)警戒費洛蒙(Alarm pheromone)：昆蟲為了達到防禦或逃避敵害之目的而分泌者，如蜜蜂、螞蟻及蚜蟲的警戒費洛蒙。(3)聚集費洛蒙(Aggregating pheromone)：昆蟲為了群聚生活在一起而分泌者，如玉米象、榖蠹、松甲蟲等的聚集費洛蒙。(4)招募或踪跡費洛蒙(Recruiting or trail following pheromone)：昆蟲為了增加搜尋食物的機會而分泌者，如蜜蜂及螞蟻的招募費洛蒙(Beroza, 1976；Chow, 1974；Jacobson, 1966,　1972；Kilgore & Doutt, 1967；Stine, 1986)。由於性費洛蒙可以誘蟲，在農林業上較有應用價值，因此被研究利用有較多的例子，在鱗翅目昆蟲，尤其是蛾類，性費洛蒙多由雌蟲分泌，可以引誘雄蟲自遠處飛來同雌蛾交尾，所以性費洛蒙常被稱為性引誘劑(Sex attractant)或性誘餌(Sex lure)(Jacobson, 1966, 1972；Shorey, 1973, 1977)。

自 1959 年第一篇家蠶性費洛蒙報告發表以來，至 1987 年累積有一千六百餘篇有關性費洛蒙的報告發表(Arn *et al.* 1986)，而費洛蒙的研究已形成一個重要的多重訓練的學門－化學生態學(Chemical ecology)，已有 20 餘本有關費洛蒙或化學生態的書籍與專刊出版，例如台北中央研究院曾於 1982 及 1988 年分別主辦國際性異體作用素與費洛蒙研討會(Seminar on Allelochemicals and Pheromones)及植物化學生態學：異體作用素、黴菌毒素、昆蟲費洛蒙及阿洛蒙研討會(Symposium on Phytochemical Ecology：Alleochemicals, Mycotoxins, and Insect Pheromones and Allomones)。1990 年捷克國家科學院於捷克塔波(Tabor)曾主辦國際昆蟲化學生態學會議(Conference on Insect Chemical Ecology)，另外，最近第一及二屆亞太化學生態學會議(Asia-Pacific Conference on Chemical Ecology)也於 1999 及 2001 年分別於中國大陸上海及馬來西亞檳榔城舉行。早期因微量分析化學技術尚未發達，昆蟲性費洛蒙的主要成分被分離鑑定出來以後，經過幾年，新的研究報告又會報導新的副成分，使昆蟲性費洛蒙組成有所改變。當新發現的副成分加入主成分調配成新的性費洛蒙配方，常會增加原來單一主成分的誘蟲效果，也因而增加其利用性。另外，早期性費洛蒙相關研究不足，而其強大又新奇的誘蟲效果，常被認為是蟲害防治的萬靈丹，但常因性費洛蒙組成分鑑定有誤或不同組成分比率不對，且相關應用技術尚未發展，即急於田間使用來直接控制害蟲發生，致未能達到預期降低作物被害度，而對性費洛蒙的效用失望。經過各國學者專家多年的研究改進，許多次的國際性研討會討論，逐漸地大家都肯定費洛蒙在害物綜合管理之角色。

至今，總計約有一千多種昆蟲性費洛蒙或引誘劑被分離、鑑定出來。昆蟲性費洛蒙的化學分子量介於 200～300 之間，多為長鏈的 C10～C18，具有 1～3 個不飽和鍵，官能基為醛(-CHO)、醇(-OH)、酯(-COOR)類物質，或松烯類的衍生物。其具有揮發性，可經空氣或水擴散到遠距離，估計在一立方厘米空氣中，只需有數百個費洛蒙分子，雄蟲即可感知費洛蒙的存在，尋線找到雌蟲的位置(Jutsum & Gordon, 1989；Kydonieus *et al.*, 1982；Ridgway *et al.*, 1990；Sondheimer & Simeone, 1970)。因此，如能分離鑑定出天然性費洛蒙的組成分，再以人工方法合成出與天然費洛蒙同具生物活性的合成性費洛蒙，即可在害蟲管理上做廣泛的利用。國際性農藥公司如 BASF、CIBA-GEIGY、ICI 及 Sandos 均加入費洛蒙研發工作。目前(1990)約有 250 種昆蟲的費洛蒙製劑已商品化(1-2 USD/lure, 4 USD/trap)，可用來偵測及誘殺害蟲，

美國環保署已核准 19 種昆蟲費洛蒙製劑，可用來防治害蟲(Ridgway *et al*., 1990)。

台灣費洛蒙研究簡述

台灣誘引物質之研發與利用始於 1911 年，日人新渡戶即以掛袋法誘殺防治東方果實蠅產卵(Liu, 1981)，並於田間實施以糖蜜加亞砒酸鉛之毒餌誘殺果實蠅成蟲；三輪勇四郎(1939, 1940)研究以肥皂水加甲基丁香油加 Lemon grass oil 混合物以誘殺果實蠅。光復後，陶氏(1952)研發氟矽酸納加糖漿加水之誘殺劑以誘殺果實蠅(Tao, 1952)，1956-1957 年之後，台灣持續使用含毒甲基丁香油及含毒蛋白質水解物(Protein hydrolysate)來誘殺果實蠅，迄今仍然沿用。

台灣費洛蒙的研究，始於 1970 年由周氏獲得農復會支助計畫，於中央研究院動物研究所開始對牛壁蝨的性費洛蒙組成分進行研究(Chow, 1982)，曾鑑定出牛壁蝨和褐狗壁蝨的性費洛蒙爲 2,6-dichlorophenol(Chow *et al*., 1975)，同時也發現壁蝨的嗅覺器官是在第一對脚之海勒器上(Chow *et al*., 1972)。當時周氏在農復會支助下，與台灣植物保護中心、台灣省農業試驗所合作，分別對斜紋夜蛾、小菜蛾等害蟲性費洛蒙的成分鑑定、合成及田間應用技術等多方研究(Chow, 1981)。

因爲害蟲的發生，常有其地域性，因此，性費洛蒙是一種地方性的資源，除非國人針對自己本地的害蟲來研發性費洛蒙，否則其他國家的研究人員不會有興趣做；也唯有國內自己開發製造本地的性費洛蒙，才可能達到普遍應用的目標。因此，國科會爲促進費洛蒙研究，乃於 1984 至 1989 年連續 6 年推動跨不同研究領域的大型整合性研究計畫--昆蟲性費洛蒙研究(Anonymous, 1990)，結合中央研究院、台灣大學、中興大學、清華大學、陽明醫學院、淡江大學、輔仁大學、農業藥物毒物試驗所、農業試驗所、茶葉改良場、桃園改良場、台中改良場、台南改良場、高雄改良場、及亞洲蔬菜研究中心等單位的化學分析、有機合成、生物學、昆蟲學及植物保護人員，針對玉米螟、番茄夜蛾、斜紋夜蛾、茶姬捲葉蛾、水稻瘤野螟(Rice leaf roller, C*naphalocrocis medinalis*)、菜心螟(Cabbage webworm, *Hellula undalis*)、球菜夜蛾及柑桔或番石榴粉介殼蟲等進行研究，同時農業委員會自 1986 年亦配合進行大規模的性費洛蒙田間誘蟲試驗。國科會前後支持 98 項性費洛蒙相關研究計畫，包括：(1)昆蟲大量飼育技術及行爲研究，(2)性費洛蒙組成分分離與鑑定，(3)性費洛蒙合成，(4)性費洛蒙配方及生物檢定研究，(5)田間應用與效益評估，總經費約六千萬新台幣。

由於國科會與農委會大力推動支助費洛蒙研究與應用計畫，自 1984-1986 年起，國內相關的試驗與研究單位有興趣於費洛蒙的研究人員也較爲增加，有關費洛蒙的研究報告才有大幅度的增加，研究的昆蟲種類除前述者外，尙包括：甜菜夜蛾、茶捲葉蛾、甘藷蟻象、

甘藷螟蛾(Sweetpotato vine borer, *Omphisa anastomasalis*) (Talekar *et al*., 1992)、二化螟、蕪菁夜蛾、大豆擬尺蠖、甘蔗黃螟、甘蔗叩頭蟲、桃折心蟲、楊桃花姬捲葉蛾、粗腳姬捲葉蛾、荔枝細蛾、桃蚜、小白紋毒蛾(Small tussock moth, *Orgyia posticus*) (Su, 1988)、台灣豆金龜與藍艷豆金龜、煙甲蟲、粉斑螟蛾、印度穀蛾、松斑天牛、及瓜、果實蠅(Yen & Hwang, 1997)等。茲將已知的台灣一些重要昆蟲的費洛蒙成分及類似物收集彙整於表二，以供同道參考(Burkholder & Ma, 1985；Kydonieus *et al*., 1982；Tamaki, 1985)。

同時，前台灣省農林廳為加強非農藥防治技術之應用，亦開始推廣教育農民使用性費洛蒙來防治害蟲，推廣的性費洛蒙種類有:斜紋夜蛾、甜菜夜蛾、甘藷蟻象、楊桃花姬捲葉蛾、及茶姬捲葉蛾等，分別應用於十字花科蔬菜、青蔥、落花生、大豆、花卉、甘藷、楊桃、及茶等作物(表三)。另推廣的誘引劑種類主要為含毒甲基丁香油、克蠅、或蛋白質水解物，用以誘殺危害各種瓜類及水果果實的瓜、果實蠅。該等性費洛蒙及誘引劑應用的方式，以偵測及大量誘殺為主，交尾干擾防治法僅小面積示範推廣於楊桃作物。

性費洛蒙之作用機制

鱗翅目蛾類分泌性費洛蒙的腺體在成熟雌蛾典型位於腹部第 8 及 9 節之節間膜內面，其具有可外翻之上皮腺(Glandular epithelium)，平常第 8 及 9 節縮進第 7 節內，而性費洛蒙分泌腺體同時凹陷入腹腔內。雌蛾分泌性費洛蒙時，會主動伸出腹末端節及腺體區，並收縮腺體，間斷地釋放出高低不同濃度的性費洛蒙。性費洛蒙在生物體內合成之過程所知不多，可能是源自食物並經代謝而形成性費洛蒙前驅物質(Precurser)，積存於性費洛蒙腺體內，再由腦與食道下神經球產生費洛蒙生物合成神經胜呔的賀爾蒙(Pheromone biosynthesis activating neuropeptide，簡稱 PBAN)，此胜呔物由 21 個氨基酸組成，分子量約為 2000 Daltons，經由血液影響費洛蒙腺體活化生成性費洛蒙(Chow, 1994)。以家蠶而言，一隻雌蛾平均含有 10ng 性費洛蒙成分(Sondheimer & Simeone, 1970)。性費洛蒙的釋放受到多種內、外在因子所控制，通常僅在一天中特定的時刻才釋放，如夜蛾科的斜紋夜蛾(Shih & Chu, 1995)、甜菜夜蛾(Cheng, 1989)，及螟蛾科的亞洲玉米螟(Hung & Hwang, 1990)、二化螟等昆蟲，多在夜晚釋放性費洛蒙；而捲葉蛾科的楊桃花姬捲葉蛾 (Hung *et al*., 1997)及介殼蟲科的柑桔或番石榴粉介殼蟲(Guava mealybug, *Planococcus minor*) (Hwang & Chu, 1987)則在白天釋放性費洛蒙。

雌蟲發情(Calling)分泌性費洛蒙時，常表現雙翅微張，腹部末端微微向上翹起，並常伴隨微微振翅行為，放出來的性費洛蒙分子即可藉著蒸發作用及昆蟲振翅時所造成之氣流，從腺體表面擴散開來，並藉空氣為媒介，傳遞信號至接受者(雄蟲)。昆蟲性費洛蒙具揮發性，

可依照簡單的擴散定律來表示其擴散情形，並可依釋放速率(Emission rate) Q (單位爲分子／秒)與反應閥限濃度(Behavioral threshold concentration)K(單位爲分子／立方厘米)之比值 Q／K，來估算性費洛蒙傳遞信號所需時間，信號消逝所需時間，及傳遞有效距離(Active space)；性費洛蒙之 Q／K 值愈高，其有效距離愈遠，且信號消退的時間愈慢(Bossert, 1963；Sondheimer & Simeone, 1970)。

雄蟲之所以能察覺化學傳訊物質，主要在觸角上的毛狀化學感覺器(Trichodea)，感覺器內有神經細胞突觸，性費洛蒙分子與突觸膜上的蛋白質接受器結合，就可以啓動腺嘌呤環化脢,然後打開 K^+或 Na^+離子通道，產生電位差而發出訊號，訊號經神經細胞傳導至中央神經系的大腦(Deutocerebrum)，再使雄蟲對嗅覺刺激引起行爲反應(Chow, 1994；Mattews & Mattews,1978；Roelofs & Carde, 1977；Shorey, 1977)。例如雄蟲觸角感受到性費洛蒙的氣味，受刺激而引發正趨風性（Anemotaxis），即從遠處向性費洛蒙源作逆風直飛，至近距離時(1m 內)，則變爲彎曲飛行（Zigzag flying），接近雌蟲時，先著陸、步行、振翅、碰觸，繼而伸出交尾器進行交尾。學者專家對於昆蟲受性費洛蒙源導向趨集的行爲反應機制有多種說法，一般認爲在無風狀態下，性費洛蒙分子從腺體釋放出來，以球形狀態向四方擴散開來，即形成一外圍濃度低而裡面濃度高的擴散梯度(Diffusion gradient)或濃度梯度（Concentration gradient），昆蟲可察覺此種不同濃度的梯度，自低濃度趨向高濃度飛行。或者在有風的情況下，風將性費洛蒙以雲團狀吹開來，形成一長橢圓形的氣味走廊（Odor corridor），雌蟲附近的性費洛蒙濃度仍較其他距離點者高，雄蟲可藉此氣味走廊找尋到雌蟲所在處，進而達到交配及繁衍子代的目的。因此，我們可利用昆蟲這種行爲習性，使用天然或人工合成的性費洛蒙，在蟲害防治上作廣泛的應用。

性費洛蒙及其類似物之應用

早在 1930 年，歐洲就曾利用含處女蛾的誘蟲器進行葡萄螟蛾（Grape berry moth, *Eupoecilia* (*Clysia*) *ambiguella*）的大量誘殺試驗(Jutsum & Gordon, 1989)。1932 年，美國昆蟲植物檢疫局的 Collions & Potts 亦曾利用舞蛾（Gypsy moth, *Lymantria dispar*）的雌性費洛蒙萃取液，每一季節以人工收集數十萬隻蛹來製備性費洛蒙萃取液，而每一誘蟲盒使用 12 隻雌蟲當量的萃取液當誘餌，來偵測該蟲的發生地點，作爲施藥防治的依據，有效地抑制該蟲的蔓延，後來因 DDT 大量使用造成後遺症，致使防治計畫於 1960 年停止(Ridgway *et al*., 1990)。唯美國農部仍繼續以性費洛蒙萃取液進行舞蛾分佈調查，1970 年舞蛾性費洛蒙 Disparlure 被鑑定合成，則改用合成的性費洛蒙做調查，於 1972 至 1977 年超過 50 萬個誘蟲器被使用；至 1977

年正確的具旋光性性費洛蒙成份被鑑定與合成，則再改用 Plus-disparlure 做調查。另外，Beroza（1960）曾認爲高濃度的性費洛蒙可干擾雌、雄蟲的交尾行爲，Gaston *et al.*（1967）首次於田間試驗證實高濃度的性費洛蒙可阻礙雌、雄蟲的交尾行爲，直到 1978 年 Albany 國際公司始成功研發出棉花紅鈴蟲（Cotton pink bollworm, *Pectinophora gossypiella*）性費洛蒙干擾劑（Gossyplure），並獲得美國環保署（EPA）的註冊登記(Jutsum & Gordon, 1989；Ridgway *et al.*, 1990)。

現就性費洛蒙及其類似物於蟲害管理之應用方式分述如下(Hwang, 1997；Jutsum & Gordon, 1989；Knipling, 1979；Kydonieus *et al.*, 1982； Lewis, 1984；Mitchell, 1981；Nordlund *et al.*, 1981；Ridway *et al.*, 1990；Shorey, 1977；Wood *et al.*, 1970)。

1.偵測或監測法（Detection or monitoring）：

即以天然或合成性費洛蒙配製成誘餌，再與適當的捕蟲器具組合成誘蟲器，然後在田間設置誘蟲器來調查、偵測及監視害蟲的發生地點或發生時期，進而估計害蟲密度，預測作物被害程度，以作爲決定施藥與否或採行其他防治措施之參考。

費洛蒙誘蟲器做爲害蟲發生偵測工具的優點是：(1)很靈敏的取樣技術，(2)具種別特異性，(3)不需用電及特別維護，(4)不需花很多人力，(5)容易操作等優點。唯亦有一些限制條件：(1)解讀所誘捕蟲數的意義，(2)誘蟲器的有效距離或取樣範圍及其效用隨時間而改變，(3)氣象因子的影響(此亦真正影響昆蟲的活動狀況)，(4)田間處女雌蟲的競爭力，(5)誘捕成蟲的時間與幼蟲爲害時間的差異問題等。

發展性費洛蒙偵測系統時，除需先開發高效的性費洛蒙誘餌，及穩定性高且標準化的誘捕器外，如何建立誘蟲數與族群密度或作物被害度之關係，及依經驗判斷（Educated guess）解釋誘捕蟲數資料所代表的生物意義，是決定誘捕蟲數資料能否被利用的關鍵所在。大面積或區域性實施偵測法時，通常每 1～10 公頃面積設置一個誘蟲器即可，如果是獨立的農田、果園，應該每塊田都有一個誘蟲器，則誘捕蟲數比較具代表性。另外，在蟲害發生早期或族群密度較低時，進行偵測的成效較佳。

費洛蒙誘器誘蟲的誘蟲資料可提供如下的用途：(1)害蟲發生偵測(Occurrence detection)：可偵測害蟲羽化、入侵新的地區或遷移發生，做爲早期預警(Early warning)。例如在機場、海關或其他害蟲可能入侵的地點，設置誘蟲器，作爲檢防疫害蟲早期警報系統，以作爲採行防治策略的依據。(2)爲害或經濟臨界監測(Threshold monitoring)：監視田間害蟲的發生期，進而預測害蟲族群的消長，或設定爲害經濟臨界(防治)指標，例如經濟臨界可設定爲害蟲大量羽化或大舉入侵，此時可決定適時施藥防治，或再進一步調查田間害蟲的卵及幼蟲數目，

以決定精準的施藥適期(Precision timed applications)，減少藥劑使用量及次數。如此不依照傳統根據防治曆施藥行預防性防治(Prophylactic spray-on schedule control approach)，可減少 50 %農藥使用量(Madsen, 1981; Wall, 1984; Antle & Park, 1986)。(3)蟲口密度估計(Density estimation)：可調查害蟲發生的相對數量，作爲評估某種防治策略之有效性，如在施藥之前及施藥之後，分別以誘蟲器誘蟲，並比較施藥前、後的誘蟲數目，如此便可簡易估計農藥的殺蟲效果。如果能建立量化的誘捕蟲數(Trap-catch)與害蟲族群密度(Population desity)間的相關性，則對害蟲危害風險評估(Risk assessment)更有效用。另外，更可進一步估評害蟲族群發生趨勢、研究害蟲棲地分散行爲，以建立更有效的防治策略。

美國加州及佛羅里達州政府每年花費數百萬美元設立果實蠅類誘捕測偵點，全面偵測可能入侵的果實蠅類害蟲，做爲檢防疫早期警報之用，並爲進一步密集調查或啓動滅絕計畫之決策參考。例如在加州於 1987 年曾設立 1 萬 5 千個甲基丁香油誘蟲器(0.8 trap/km^2)、3 萬 3 千個 Trimedlure 誘蟲器度(2 traps/km^2) 及 7 千個克蠅(Cuelure)誘蟲器，分別偵測入侵的東方果實蠅、地中海果實蠅(Medfly, *Ceratitis capitata*)及瓜實蠅，當第一次偵測有果實蠅入侵，立即於偵測點周圍做更密集的調查(Intensive survey)，如果再偵測到確實有果實蠅入侵，則啓動滅絕計畫(Eradication program)。

對地中海果實蠅而言，當入侵果實蠅第一次被偵測，則在 48 小時內於發現地點周圍 210 km^2 面積加設 1 千 7 百個誘蟲器，其中 100 個設立於發現地點周圍 2.59 km^2 面積內，另外在其周邊每 15 km^2 面積設置 50 個誘蟲器，由發現地點向周邊延伸 7 公里。假如進一步密集調查沒有捕獲果實蠅，而且果園內果實也檢查不到幼蟲，則密集調查持續 3 代時間即停止操作。但是如果密集調查捕獲更多果實蠅，則需啓動滅絕計畫。結果顯示第一次偵測有果實蠅後經密集調查，50 %事例不會進一步捕獲更多果實蠅，不需啓動滅絕計畫。

加州地區東方果實蠅滅絕計畫使用誘殺劑配方是 70 %甲基丁香油混合 10 %殺蟲劑與 20 %黏稠劑，很像霜淇淋黏度，將誘殺劑施用於路邊電線桿與行道樹離地 180 cm 高處，每株劑量 5 ml，施藥密度是 230 點/km^2。施藥面積由果實蠅發現地點周圍半徑 2.4 km 面積(約 23 km^2)，每 2 週施藥一次連續施藥 2 世代期間，通常約在 3 個月期間施藥 6 次。該果實蠅誘殺劑並未經美國環保署註冊登記，而是屬緊急防治用藥免除登記。本果實蠅滅絕計畫於 17 年間曾被施行約 12 次，累積處理面積達數百平方英里，都獲致成功結果。

加拿大、英國及蘇俄等國，曾設定蘋果蠹蛾（Apple codling moth, *Cydia pomonella*）的誘蟲數達每週每個誘蟲器捕獲 5 隻時，即需施藥防治，依此可減少 50～75 % 的噴藥次數。以色列亦利用性費洛蒙誘蟲器來偵測棉花紅鈴蟲的發生，認爲每誘蟲器每晚捕獲 8～9 隻時，

可預期 10 日後有 10 % 棉鈴受害，應該施藥防治，依此僅需施藥二次即可有效防治本蟲，而農民傳統需要施藥 10～15 次。

臺灣在性費洛蒙偵測害蟲發生之利用上，黃氏曾研究以處女雌蟲誘蟲器來偵測番石榴粉介殼蟲的發生爲害，發現每公頃設置一個誘蟲器即可偵知雄蟲飛行活動狀況，而誘捕雄成蟲數與雌成蟲發生數具顯著性之正相關關係，亦即粉介殼蟲雌性費洛蒙誘蟲器可利用來偵測田間族群發生，以提供防治策略及防治時機的情報(Hwang & Chu, 1987a, b)。石與朱亦報告於甘籃菜田以合成性費洛蒙誘蟲器來偵測斜紋夜蛾的發生爲害，認爲每公頃設置一個誘蟲器，在移植期每週誘蟲器累積誘蟲數達 68 隻，或於葉片肥大期及結球期每週誘蟲器累積誘蟲數分別達 113 及 157 隻，即達經濟防治基準，應於 2 週內施藥防治(Shih & Chu, 1995)。利用甲基丁香油誘殺器已建立全省東方果實蠅發生密度監測網，可依照誘殺果實蠅蟲數決定不同的防治措施(TARI, 1995)。黃與顏試驗推測瓜、果實蠅在冬季被誘殺蟲數降低，是由於冬季寄主食物減少，且因低溫使瓜、果實蠅產卵、發育與繁殖率均降低所致，而非冬季低溫使甲基丁香油及克蠅誘引力降低所致(Hwang & Yen, 1998)

我國即將加入世界貿易組織(WTO)，國外農產品輸入台灣的種類、數量及進口地區均將擴大，可能夾帶檢疫害蟲而入侵台灣的機會亦將大幅增加，將影響國內農業生產環境及國人健康安全，因此，可利用性費洛蒙誘蟲器佈建偵測站，以攔截境外入侵的外地害蟲，做爲預警及決定緊急防治之參考。另外，將來宜繼續加強研發各種重要害蟲的誘捕偵測系統，及累積足夠的基礎資料，再教育農民增加性費洛蒙有關的知識水平，使能對誘蟲資料作經驗判斷，以便利用性費洛蒙誘蟲器來標定害蟲發生的位置及時機，提供寄生蜂釋放、適期藥劑防治、或危害程度判斷之參考。

2.大量誘殺法或滅雄法（Mass trapping or attraction-annihilation）：

即於作物栽培區，大量設置性費洛蒙誘蟲器或撒佈含毒誘餌，移走或誘殺田間大多數的雄蟲（甚至達滅雄程度），以降低雌蟲成功交尾的機會，進而抑制害蟲的產卵量及次代的族群密度，以減少作物被害率。

大量誘殺法是基於誘殺器與田間雌蟲對雄蟲競爭誘捕及交尾的理論，故單獨使用誘殺器來防治害蟲時，在高族群密度下或雄蟲找尋雌蟲交尾潛力(Male mating potential, MMP)大於 5 時，須設置足夠數目且高誘殺效率的誘殺器，能夠誘殺 80～90 % 以上的雄蟲，才能確實降低害蟲次代的族群密度(Kydonieus *et al*., 1982；Ridgway *et al*., 1990)。但是在低族群密度下，MMP 可能小於 1 時，少量的雄蟲被誘殺即可降低次代族群的密度。如果費洛蒙可對雌蟲或兩性引誘時，或者，先用殺蟲劑降低害蟲幼蟲的密度，再對成蟲或越冬世代的成蟲進行大

量誘殺，則大量誘殺法的成效可增加很多。另外，性費洛蒙與天敵、微生物製劑、荷爾蒙及不孕劑等合用，都能增強綜合防治害蟲的效果。大量誘殺法，有時在不同地區實施的成效不一致，有人認爲對害蟲大量誘殺防治成功，是由於誘蟲器的設置而減少藥劑的使用，使得天敵發揮應有的效用所致。

實施大量誘殺法時，如何提高誘蟲器的誘殺效率，及決定單位面積設置誘蟲器的數目是重要的前提，設立誘蟲器的密度可由設立的誘蟲器單位誘殺蟲數或總誘殺蟲數不再增加時的誘蟲器數目來決定，或由誘蟲器的有效距離來推估。誘蟲器可與其他方法合用，如對趨光性害蟲，可與誘蟲燈合用，或與農藥配合使用，均可增加誘蟲器的誘殺效率。另以電腦模擬害蟲在無遷移狀況下，每公頃使用 25 個以上誘蟲器，較能有效抑制害蟲發生；惟單位面積設置誘蟲器的數目，常受實際害蟲密度之影響，且應注意誘蟲器的設置宜配合害蟲的分佈型式。

性費洛蒙使用在農業、森林、及倉庫害蟲的效用各有不同。一般倉庫或糧倉的環境屬相當隔離、封閉性空間，且溫濕度及光照等因子也很穩定，而倉儲害蟲的成蟲多可直接取食爲害倉儲穀物，其密度低不易察覺又具快速增殖能力，加上倉儲害蟲分泌的費洛蒙多屬聚集費洛蒙，對雌、雄性都具引誘性，因此，利用費洛蒙配合殺蟲劑來大量誘殺防治倉儲害蟲，更具應用潛力(Burkholder & Ma, 1985)。另外，可使用費洛蒙將倉儲害蟲引誘到置放有病原微生物胞子處，使其接觸胞子而感染發病死亡，甚至可將孢子傳播至其他害蟲，造成流行病(Shapas *et al.*, 1977)。現今不似 1970 年糧食危機時代，且米穀多貯放於公有倉庫，倉儲害蟲防治未被重視，因此，費洛蒙在台灣的倉儲害蟲管理上仍有很大應用空間。

對森林害蟲而言，以費洛蒙大量誘殺法結合餌木誘殺與砍除被害林木的綜合防治法，對某些樹木甲蟲是相當有效的降低害蟲族群密度的方法(Bestman & Vostrowsky, 1988)。例如 1970 年加州對西方松木甲蟲(Western pine beetle, *Dendroctonus* brevicomis)進行大量誘殺計畫，結果未處理前每年樹木死亡 283 株，處理後降爲 30 株以下。挪威亦曾使用赤松小蠹蟲(Spuce bark beetle, *Ips typographus*)的聚集費洛蒙進行大量誘殺法，而獲得良好的防治效果，1976 年大量誘殺前因小蠹蟲爲害每年損失 3 百萬株松樹，於 1979-1980 年 1 年期間使用 60 萬個誘蟲器大量誘殺 74 億隻小蠹蟲，結果 1982 年被害松木降爲 20 萬株(Lie, 1984)。

以性費洛蒙大量誘殺農業害蟲具有成效的事例更多，Sternlicht (1982, 1986)在以色列進行檸檬樹 Citrus flower moth (*Prays citri*)的大量誘殺工作，連續三年每公頃果園設置 120 個誘蟲器防治該蟲，結果大量誘殺的果園的花朵被害率較傳統施用殺蟲劑果園降低 38~50 %。Madsen *et al.* (1976)在隔離的果園且蘋果蠹蛾密度較低時，每公頃設置 10 個誘蟲器，結果達

到滿意的防治效果。Teich *et al.* (1985)報導以色列曾於數千公頃的棉花田連續四年以性費洛蒙大量誘殺法防治 Egyptian cotton leaf worm (*Spodoptera littoralis*)，結果大量誘殺的棉花田較傳統殺蟲劑的田被害率減少 20~45 %，目前，大量誘殺法已成爲以色列棉花生產中害物綜合防治策略的重要部分。利用費洛蒙來偵測誘殺棉鈴象鼻蟲(Cotton boll weevil, *Anthonomus grandis*)一向是美國對該蟲區域滅絕計畫中重要防治策略之一(Legget *et al.*, 1988)，1988 年在美國東南部，包括南北卡羅來納州、喬治亞州、阿拉巴馬州及佛羅里達州總計有 158,800 ha 棉田，使用 59 萬個誘蟲器及 825 萬個性費洛蒙誘餌來大量誘殺棉鈴象鼻蟲，結果將該蟲實際地消除。1988 年在美國西南部，包括加州南部、亞歷桑納西南部及部分墨西哥州，曾以 1-2 trap/4 ha 密度使用 5 萬個誘蟲器及 120 萬個誘餌進行棉鈴象鼻蟲大量誘殺計畫，結果使棉田殺蟲劑使用量減少 50-70 %，棉花種植面積及產量增加，年報酬超過 187.5 USD/ha。世界各國曾以大量誘殺法來防治夜盜蟲（Cutworm,*Spodoptera* spp.）的發生爲害，結果成效不一：以色列曾於 3,000 公頃的農田，以每公頃設置 2 個誘蟲器，結果可減少 30～40 % 農藥施用次數；日本則認爲每公頃設置 9 個誘蟲器時，誘殺蟲數最高，惟每公頃需設置 15 個以上的誘蟲器，始可降低雌蛾交尾率。

1912 年 Howlett 於印度首次發現香茅油(Citronelia)中的甲基丁香油(Methyl eugenol)和異丁香油(Iso-eugenol)對果實蠅(*Dacus sp.*)具顯著的誘引性(Howlett, 1915)，直到 1952 年 Steiner 才再度發現甲基丁香油的利用性。因此，Steiner *et al.* (1965)於 65-km^{2}的 Rota 島，以 8.5 g/ha 劑量撒布含 5 %乃力松甲基丁香油的棕櫚纖維板(5 cm^{2}含 24 g 混合藥液)，以大量誘殺滅雄法在一年期間就將該島嚴重發生的東方果實蠅滅絕。自 1957 年以來，美國農部在加州及佛州持續利用含毒誘殺劑，來滅絕定時入侵該州的東方果實蠅與地中海果實蠅。因此，只要誘殺劑較天然誘引物質特別強有效力，而且處理地區較隔離，即使僅誘殺大量雄蟲，仍可因滅雄而滅絕害蟲。

臺灣李氏（1985）曾於 10 公頃以上的大豆田，每公頃設置 5～10 個誘蟲器大量誘殺斜紋夜蛾，結果處理區的被害葉率可減少 53 % ，而且每公頃防治成本可節省新台幣 1,500 元(Lee, 1985, 1989)。顏等人（1991）曾試驗於落花生播種後，每公頃放置 4～5 個斜紋夜蛾性費洛蒙誘蟲器，8～9 個甜菜夜蛾性費洛蒙誘蟲器，及 13～18 個番茄夜蛾性費洛蒙誘蟲器，綜合防治三種夜蛾科害蟲，結果顯示落花生生育期間可減少 60 % 之幼蟲數，被害葉率則較未誘殺區減少 40.7 % (Yen *et al.*, 1991)。鄭等人（1991）報告於 500 公頃青蔥田，每公頃放置 30 個甜菜夜蛾性費洛蒙誘殺器，可減少 20 % 幼蟲數，青蔥生產量提高 24 % (Cheng *et al.*, 1989)。黃等人（1989）曾開發甘藷蟻象性費洛蒙誘餌及誘蟲器，其再捕率可達 82～97 % ，

田間試驗結果顯示每分地設置 4 個誘蟲器，可減少甘藷被害率達 65 ％ ，若與藥劑配合防治甘藷蟻象，每公頃防治成本約可節省新台幣 7,000 元(Hwang, 2001; Hwang *et al*., 1989, 1990；Hwang & Hung, 1991, 1992, 1994; Yen & Hwang, 1997)。邱氏（1987）於 540 公頃的小琉球島，以每月每公頃投放 4 個含毒甲基丁香油纖維板的用量，進行大量誘殺東方果實蠅試驗，經連續投放毒餌一年後，可將該島的東方果實蠅滅雄，達到完全防治的效果(Chiu, 1987)。

利用性費洛蒙誘蟲器大量誘殺害蟲的方法，較易為農民所接受，因為農民可看到數百、或成千上萬的成蟲被誘殺，常誤認為防治有效。目前我國農政單位推廣大量誘殺斜紋夜蛾、甜菜夜蛾、茶姬捲葉蛾、甘藷蟻象及楊桃花姬捲葉蛾的防治工作(Hung & Hwang, 1993; Hwang & Hung, 1994; Hwang *et al*., 1995)，宜儘量提高單位面積設置誘蟲器的數目，較易達到成效，但若因此促使農民減少用藥次數及藥量，當屬有經濟效益。

3.交配干擾法或迷惑法（Mating disruption or confusion method）：

Beroza（1960）首次提出，認為於田間維持高濃度的性費洛蒙，將可干擾或阻礙雌、雄蟲正常的交尾行為，終至影響害蟲的生殖，並抑制其族群發生。Gaston *et al*. (1967)首次於田間試驗證實擬尺蠖性費洛蒙行交配干擾法具可行性。由於 Shorey 和 Brook 的努力試驗與推動(*Brooks et al*., 1979)，1978 年美國環保署首次核准由 Albany International Corp.提出的棉花紅鈴蟲性費洛蒙干擾劑的商品化註冊登記，而且於 1982-1986 年在南加州及亞歷桑那州有數萬公頃棉田使用該干擾劑。

交配干擾法之作用機制尚未完全明瞭，推測是：(1)昆蟲的週圍神經系統（觸角感覺器及受器）對高濃度的性費洛蒙產生適應性（Adaptation）及中央神經系統產生習慣性（Habitation）；(2)處女蟲的天然性費洛蒙受到高濃度合成性費洛蒙的掩蔽作用（Camouflage or mask）；(3)在高濃度性費洛蒙環境中，雄蟲的感覺器對天然的性費洛蒙產生失衡作用（Imbalance）；(4)高濃度的合成性費洛蒙源與處女蟲之間產生競爭作用（Competition or false-trail following）等各種作用，造成雌、雄蟲無法正常交尾而繁衍子代(Bartell, 1982)。理論上，雌蛾交尾抑制率要達到 70～95%以上，才屬防治有效。目前證據顯示以完整的天然費洛蒙組成分比例最具交配干擾作用(Minks and Carde, 1998)。

世界各國曾對茶姬捲葉蛾、小菜蛾、甜菜夜蛾、楊桃花姬捲葉蛾、蘋果蠹蛾、桃折心蟲或東方果蛾（Oriental fruit moth, *Cydia* (*Grapholita*) *molesta*）、Tomato pinworm (*Keiferia lycopersicella*)、桃樹蛀蟲(Peachtree borer,*Synanthedon exitiosa* ；Lesser peachtree borer,*S. pictipes*)、葡萄螟蛾、棉花紅鈴蟲、舞蛾、西方松甲蟲（Western pine beetle,*Dendroctonus brevicomis*）等 20 餘種害蟲，進行干擾試驗，證實確可達到有效防治的結果。通常性費洛蒙

施用量若不足夠（5～20 克/公頃），則無法發揮干擾交尾的效果，因此，性費洛蒙用量常要達 50～200 克／公頃以上，始能有效抑制害蟲發生。

國內黃和洪（1997）曾研發楊桃花姬捲葉蛾性費洛蒙交配干擾用緩釋劑型，並利用該合成性費洛蒙干擾劑進行該蟲交配干擾試驗(Hwang & Hung, 1997a,b)，干擾劑用量為 52～67 克／公頃，其持效性約可達 5 個月，干擾劑施放期間，處理果園的誘引抑制率及交尾抑制率分別為 94.6～100 ％ 及 48.0～96.3 ％ ，處理果園的果實被害率較傳統殺蟲劑施用果園減少 11～72 ％ ，防治成效顯著。

多種昆蟲性費洛蒙已被製成緩釋劑型（Slow-releasing formulation），於田間施用時，可採用每數公尺設置高劑量的性費洛蒙干擾劑之疏布釋放方式，或者可像殺蟲劑一樣地以器械及飛機從地面或空中撒佈田間，來控制害蟲發生。例如美國 Hercon 公司出品的片劑（Trilaminates or flakes）、Scentry 公司的中空管（Hollow fibers or capillaries），Fermone 公司的 Liquid flowable，英國 ICI 公司的微膠囊（Microcapsules），及日本信越公司的塑膠管或微粒（Polyethylene ropes or particles）等。惟目前性費洛蒙合成品的售價多屬昂貴，因此未來如何改進合成的路徑，及放大合成的產量，以降低合成品的售價，是一重要課題。據報告稱目前每年性費洛蒙的需求量不超過 2 公噸，如果每年需求量增加為 100 公噸，則擴大產能，有可能使產品價格降至每公克為 0.05～0.15 美元，如此，性費洛蒙用於交配干擾法始屬經濟可行。另外，私人廠商能積極參與費洛蒙的產銷，亦有助於費洛蒙應用，早日從試驗階段進入商業化時代。

由於性費洛蒙的作用機制不同於傳統的藥劑，因此在評估大量誘殺法及交配干擾法對抑制害蟲發生的有效性時，不能僅從誘殺雄蟲數多寡來評斷，宜從雌蟲交尾成功率、田間受精卵數、次代幼蟲或蛹存活數、及作物被害度等來評估較正確。利用性費洛蒙來防治害蟲時，需大面積施用較有效，因此常不易找到生態環境相類似的大區域，同時進行不同的比較處理或多次重複，且性費洛蒙試驗材料及調查的人工費用鉅大，故在缺少比較處理組和對照組及重複調查數據不易收集下，致防治效益不易評估，或統計上無法比較，此宜由多年重複試驗結果來判斷防治效益。

4.性費洛蒙與殺蟲劑合用對付抗藥性害蟲:

針對某些抗藥性害蟲，可施用殺蟲劑殺死多數害蟲，部分具抗藥性害蟲未能被藥劑殺死，可同時利用性費洛蒙誘殺殘存的抗藥性害蟲，則可減緩害蟲抗藥性的產生，又可增加殺蟲劑的殺蟲效果。另外性費洛蒙誘蟲器可有效地被用來偵測害蟲的抗藥性程度(Riedl *et al*., 1985； Haynes *et al*., 1986, 1987)，也就是在性費洛蒙誘蟲器之黏膠層或水層中，添加不同劑

量的殺蟲劑，觀察被誘捕昆蟲在一定時間內的死亡率，再估計昆蟲對殺蟲劑的抗藥性程度。此種抗藥性監測法具快速又容易操作特性，對農事指導人員及農民需快速決定田間殺蟲劑的效果有很大的助益。在紐西蘭果樹生長區，性費洛蒙曾被使用來誘捕不同地區的雄性昆蟲，再以背部局施藥法(Topically testing)檢測來自不同地區的害蟲對殺蟲劑的抗藥性程度，以快速決定施用殺蟲劑的種類(Suckling *et al*., 1985)。

5.性費洛蒙可兼作其他用途：

(1)可利用性費洛蒙特具的種性別，協助近緣害蟲種類的鑑定，例如對臺灣亞洲玉米螟（*Ostrinia furnacalis*）及歐洲玉米螟（*O. nubilalis*）的釐清(Hwang *et al*., 1985,1990; Lo *et al*., 1989；Yeh *et al*., 1989)；番石榴粉介殼蟲（*Planococcus minor*）及柑桔粉介殼蟲（*P. citri*）的發現及區辨(Hwang & Hung, 1988)；臺灣荔枝細蛾（*Conopomorpha sinensis*）與馬來西亞可可細蛾（*C. cramerella*）種類調查(Hwang & Hung, 1996; Hwang *et al*., 1996)，均有重大貢獻。(2)作爲研究害蟲遷移分散行爲及族群動態之工具。(3)有些性費洛蒙兼具開洛蒙〈利它素〉的作用，可被利用來增強寄生蜂尋找害蟲的能力，以提高害蟲被寄生率。(4)可於大面積作物栽培區內的局部作物，施用性引誘劑，引誘害蟲大量聚集於陷阱作物（Crop trapping）上，再撒佈藥劑殺除之，則可增加防治效果並減少藥劑使用範圍及藥量。

費洛蒙之使用安全與商品化註冊登記

性費洛蒙和化學引誘劑與傳統殺蟲劑比較，對人體與環境是相當安全的物質(表四)。Inscoe *et al*. (1990)報告已商品化的費洛蒙產品約有 300 種，其中使用在偵測法者最多爲 230 種，其次者爲大量誘殺法有 30 種，交配干擾法有 18 種，其他方法如誘殺劑(Attracticide)等者有 24 種；在鱗翅目昆蟲應用最多，其次者爲鞘翅目昆蟲。費洛蒙及其類似物在美國各地已被廣泛地使用，多數由政府機構包括聯邦政府、州政府、及地方郡或縣政府與合作農場購買使用。主要使用方式有二類:一是防治計畫(Control program)，包括大量誘殺、交配干擾法、及誘殺劑；另一是調查計畫(Survey program)，針對遷移性夜蛾科害蟲如 *Heliothis zea* 與 *Spodoptera frugiperda* 等需區域性聯合管制的害蟲。各別農户使用較零星，因性費洛蒙技術一定要對農户有需要及利益，可用來直接防治害蟲或對決定施藥時間有助益，才易被農民接受採用，例如 Tomato pinworm 性費洛蒙已商品化且應用技術成熟，政府已不需要再花錢推廣。屬全國性的害蟲及外來檢疫害蟲由聯邦政府執行偵測工作，州政府則需對當地特定的害蟲如棉鈴象鼻蟲與舞蛾進行誘殺工作，例如加州、佛州及德州政府對外來害蟲地中海果實蠅與東方果實蠅持續進行偵測工作，以決定是否啓動滅絕計畫。1986 年全美國問卷調

查結果顯示，當年有 225,000 誘蟲器被使用來偵測害蟲(不含私人使用，故數量可能低估)，其中州政府設立的誘蟲器最多佔 51.5 %，其次為縣政府及聯邦政府分別佔 22.7 及 22.5 %，私人農企業設立誘蟲器數量最少僅為 3.3 %。因此，目前利用性費洛蒙偵測害蟲發生似仍是政府必須負擔的工作。利用性費洛蒙來偵測外來害蟲的入侵相當有效果，例如 1984 年曾攔截到入侵害蟲達 2 萬 8 千次，目前美國農部有計畫針對 14 種外來害蟲進行偵測誘殺工作。

1980-1983 年間，荷蘭、英國、法國及美國等四國曾聯合成立”前導研究小組”(Pilot study group)，收集世界各國有關費洛蒙註冊登記所需的資料要件，結果於 1983 年 4 月僅美國基於費洛蒙即是非農藥另類害蟲防治劑，政府應簡化註冊程序，以增加其使用機會之考量，曾建立”層級試驗方案”(Tier-testing scheme)，費洛蒙商品化註冊登記除了產品化學特性(Product chemistry)的資料需求如傳統農藥一樣外，其他毒理及殘留量等資料需求，由簡單到複雜，視情況而定(Case by case)。事實上，商品化的費洛蒙干擾製劑，Gossyplure HF (Pink bollworm pheromone in hollow fiber formulation)在 1978 年首次獲得美國環保署的登記許可。1979 年美國環保署基於費洛蒙一些特性：(1)天然發生的化合物，(2)對象害蟲專一性，(3)一般無毒性，(4)非毒殺作用機制，(5)低使用量等特性，而將費洛蒙分類屬非傳統農藥的生化物質(Biochemicals)中的化學傳訊素(Semiochemicals)類；另一類為微生物製劑(Microbial control agents)。並基於評估化合物三項考量：(1)暴露量潛力(Exposure potential)，(2)最大危害試驗(Maximum hazard testing)，(3)不同層級試驗方案下，已有共識簡化費洛蒙註冊登記所需資料需求。

在美國(或加拿大)，如果費洛蒙不與農藥混合使用，且由誘蟲器(或陷阱作物)釋放，亦即費洛蒙以偵測及大量誘殺使用，則不需要註冊登記。如果化合物使用面積在 2.5 ha 以下，且無商業利潤，則不需要申請”試驗許可”(EUP)。如果誘蟲盒中的費洛蒙含有傳統殺蟲劑，及交配干擾用費洛蒙製劑，則需提供毒理、殘留量等資料，以供註冊登記之用；唯交配干擾劑使用量在 50 g/ha 以下，則可免除殘留量資料需求。

但是廠商認為費洛蒙既然是相當安全的天然化合物而且用量很少，註冊登記所需的資料應該更簡化，否則由於費洛蒙具專一性，只能對付單一害蟲，市場有限，只有大公司有能力發展費洛蒙製劑，而且只針對主要作物的害蟲種類或與農藥混合使用，才具有應用的經濟效益(Cost-efficient)。目前費洛蒙申請註冊登記的過程仍太費時及成本太高，因此廠商投資研發的意願不高，故政府研究單位宜支持研發經費，甚至提供註冊登記所需毒理資料的製備，或將相關毒理資料公開化，可讓大家無償或付費使用。或者，可依費洛蒙結構分類，例如:酯類(Esters)、醇類(Alcohols)、醛類(Aldehydes)等，屬同類的費洛蒙其動物毒理試驗結果

可引用，以減低交尾干擾劑註冊登記的時間與成本，另外政府與學校相關研究單位能在研發經費與行政程序上協助，才能加速費洛蒙的商品化與擴大使用。

目前在台灣性費洛蒙的上市註冊登記，只需要物理化學特性與分析方法的資料，及性費洛蒙誘餌誘引生物活性的資料，不需要急毒性與慢毒性毒理、及殘留量資料，以鼓勵性費洛蒙製劑之商品化與推廣利用。省農會農化廠已取得斜紋夜蛾與甜菜夜蛾性費洛蒙的商品化註冊登記。

結語及展望

Klassen *et al.*（1982）回顧以往性費洛蒙及其類似物研發及利用的情形，在已知的 610 種昆蟲費洛蒙當中，有 193 種用在調查及偵測法，12 種用在大量誘殺法，3 種用在干擾法。費洛蒙用在調查及偵測法，以鱗翅、雙翅及鞘翅目昆蟲所佔比率較多；用在大量誘殺法，以雙翅及鞘翅目昆蟲較多；用在迷惑法，則僅有鱗翅目昆蟲。他們認爲與傳統藥劑開發成功而上市的機率僅 0.01%比較，費洛蒙被利用的比例不算低，但因多屬輔助的防治工具，故不能算很成功(Lewis, 1984)。性費洛蒙不具毒性，所以費洛蒙是否能商品化，有關註冊登記所需的毒理資料較不是問題，而田間的應用技術及經濟效益問題才是真正關鍵所在。Wall（1984）亦認爲目前昆蟲化學傳訊素的研究與發展有些偏失，即太重視某些〝時髦〞的研究主題：如非重要害蟲費洛蒙及其類似物成分鑑定，經常特別企圖利用費洛蒙來壓制害蟲族群等；而忽略了許多田間應用有關的研究主題：如誘捕蟲數與經濟防治基準相關性之研究，田間害蟲對合成性費洛蒙的反應行爲，昆蟲生活期間不同化學傳訊素之相對重要性，費洛蒙組成分配方，費洛蒙化學物質在環境中之分散行爲，某些重要害蟲費洛蒙組成份之再鑑定等(Lewis, 1984)。未來對性費洛蒙及其類似物的研究方向宜正確把握，才能增加彼等在田間實際利用成功的機會。

由於性費洛蒙利用於蟲害防治的作用機制是改變害蟲正常的行爲，而非傳統殺蟲劑是直接對害蟲產生毒殺效果，故性費洛蒙利用於各種害蟲的防治，無法一體適用，都能產生經濟有效的結果。Campion（1984）認爲在評估什麼種類的作物害蟲較適合利用性費洛蒙來作防治，可由：(1)現行害蟲的防治方法是否需要改弦更張，(2)費洛蒙研究現況，(3)害蟲生物學基本資料，及(4)害蟲爲害特性資料等四方面，分別考量評分，再作總的評斷，將可使費洛蒙的研發及應用更適切(Lewis, 1984)。個人認爲利用性費洛蒙來控制害蟲發生，應注意下述要點及對付的害蟲種類，較易發揮防治效果：(1)宜採預防策略，於害蟲發生早期或低密度時即使用；(2)處理面積宜較隔離、或大於害蟲的移動範圍，以減少懷卵雌蟲再侵入，

而減低防治效果；(3)多與其他防治方法合用，發揮綜合防治的效果；(4)作物的經濟防治基準較高或低；(5)作物的害蟲相較簡單或害蟲屬單一關鍵害蟲；(6)甲蟲類害蟲或危害期爲成蟲期；(7)世代長；(8)單（寡）食性；(9)遷移性小，如毒蛾雌蟲不活動；(10)抗藥性害蟲；(11)殺蟲劑較不易觸及的鑽莖蛀果或地下害蟲，如咖啡木蠹蛾、楊桃蛀蟲、甘藷蟻象等。

利用性費洛蒙來防治害蟲是種高科技，而化學傳訊素（性費洛蒙），從基礎研究到實際利用，涵蓋的學門範圍相當廣泛，包括形態學、生理學、生態學、行爲學、化學、蟲害防治學等，需要研究的項目及開發的技術亦極爲繁雜(圖三)，須要多種學門的研究人員，長期持續地通力合作始能成功。將來臺灣性費洛蒙之研發與應用，宜包括幾項工作：(1)本土主要作物重要害蟲性費洛蒙組成分之分離與鑑定—以往臺灣昆蟲性費洛蒙之應用，多引用國外已知的性費洛蒙組成分，國人對於臺灣本地重要害蟲性費洛蒙組成分多缺乏研究，致阻礙了某些本地重要害蟲性費洛蒙應用之工作。(2)簡易大量合成方法之研究—有些性費洛蒙組成分並未商品化，宜由國人自行研發大量合成技術，以應研究及應用所需。(3)生物檢定技術及性費洛蒙配方之研究—建立簡易及再現性高的生物檢定方法以測試天然及合成性費洛蒙之生物活性，另性費洛蒙誘蟲配方宜著重組成份純度、比率、劑量、劑型、釋放速率、及持久性等之研究。(4)誘捕系統之設計—誘捕器構造、外形、大小、顏色、殺蟲方式、設置數目、位置、高度等均需詳加考量。(5)經濟效益評估—除由誘殺蟲數多寡來概略評斷外，宜從雌蟲交尾成功率、受精卵數、次代幼蟲或蛹存活數、及作物被害度來評估較正確。(6)推廣教育—性費洛蒙的作用機制及使用方法異於傳統藥劑，故需加強教育農民正確使用性費洛蒙的技術及基本知能。希望在有志之士共同努力研究與推廣之下，性費洛蒙及其類似物在台灣的植物檢疫與防疫及蟲害管理體系中，未來能扮演更重要的角色，提供更適切、成功的應用途徑，以促進殺蟲劑更合理的使用，並確保生態環境的品質。

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Application of Sex Pheromones in Insect Pest Management and Their Prospects

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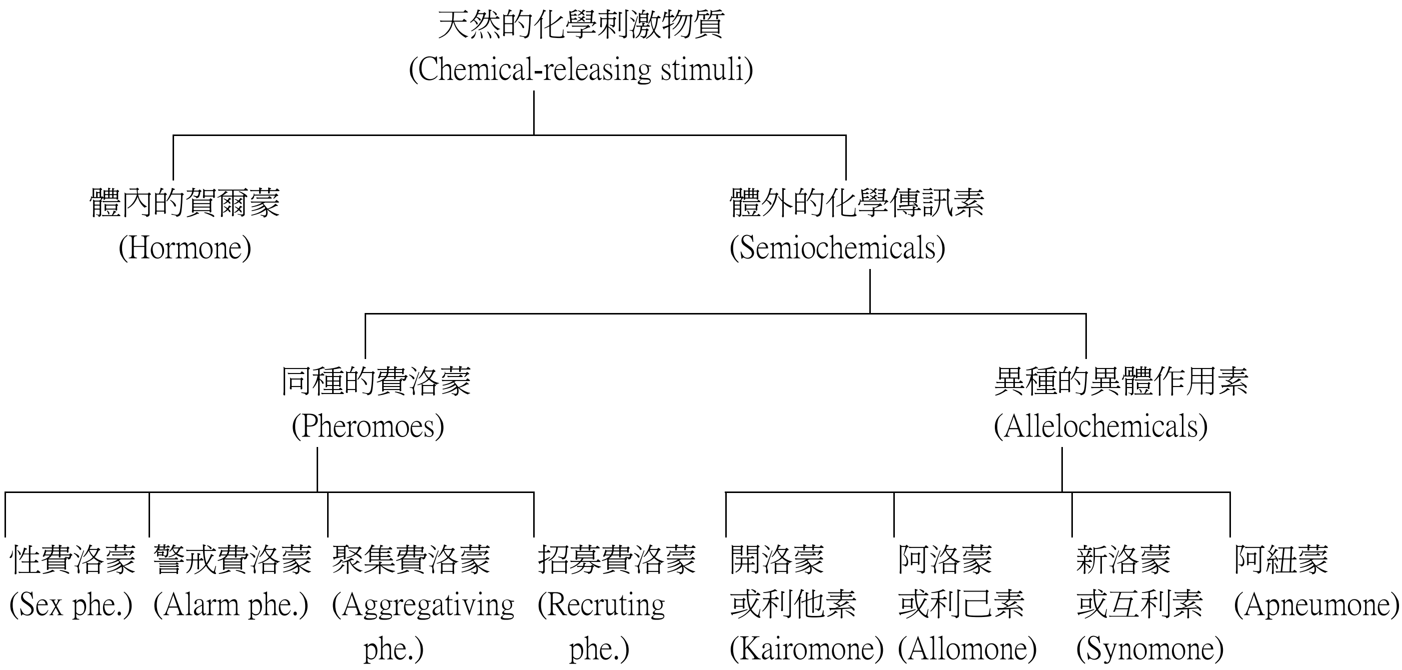
ABSTRACT

The great advances in analytical and synthetic chemistry over the past three decades, coupled with sophisticated behavioral research, has led to the identification of many semiochemicals from insects and plants which can be used to modify insect behavior, physiology, reproduction, and even to affect insect survival. Sex pheromones（also called sex attractants）is one kind of semiochemicals which possessed some characteristics include natural occurrence, nontoxic, high bioactive, species specificity, long potency, and compatibility with other control measures especially biological control, etc., that make sex pheromones as an environmental-friendly biorational pesticides. So far, about one thousand of insect pheromones are isolated, identified and synthesized, among them, about three hundreds of sex pheromones and related compounds are practiced worldwide in insect pest management programs. The main uses of insect sex pheromones include :（1）survey and monitoring with pheromones for early-warning, quarantine work, timing of control measures, population trends, dispersion, risk assessment, and effects of control measures, etc. ;（2）mass trapping and （3）mating disruption in large-scale with sex pheromones and other attractants to suppress mating and reduce the damage caused by the next generation;（4）another use measures such as be used to detect the occurrence of insecticide-resistant insects in the field, assisting closely related species identification, using as a tool of investigating dispersal and migration behavior, sex pheromones possessed kairomone function can be used to enhance natural enemy effectiveness, and can be used as crop trapping, etc.. The research and development of sex pheromones and employment in insect pest management is a multidisciplinary team-work and a high technique application. In the future, the work of R & D of sex pheromones in Taiwan should be included：（1）isolation and identification of sex pheromones for native key insect pests；（2）developing the simple synthesis methods for local insect sex pheromone components；（3）developing pheromone bioassay technique and research on the pheromone lure formulations；（4）trapping system designs；（5）efficacy and cost-effectiveness evaluation for pheromone use；（6）extensive education for farmers, etc.. The sex pheromones and related chemicals with their unique

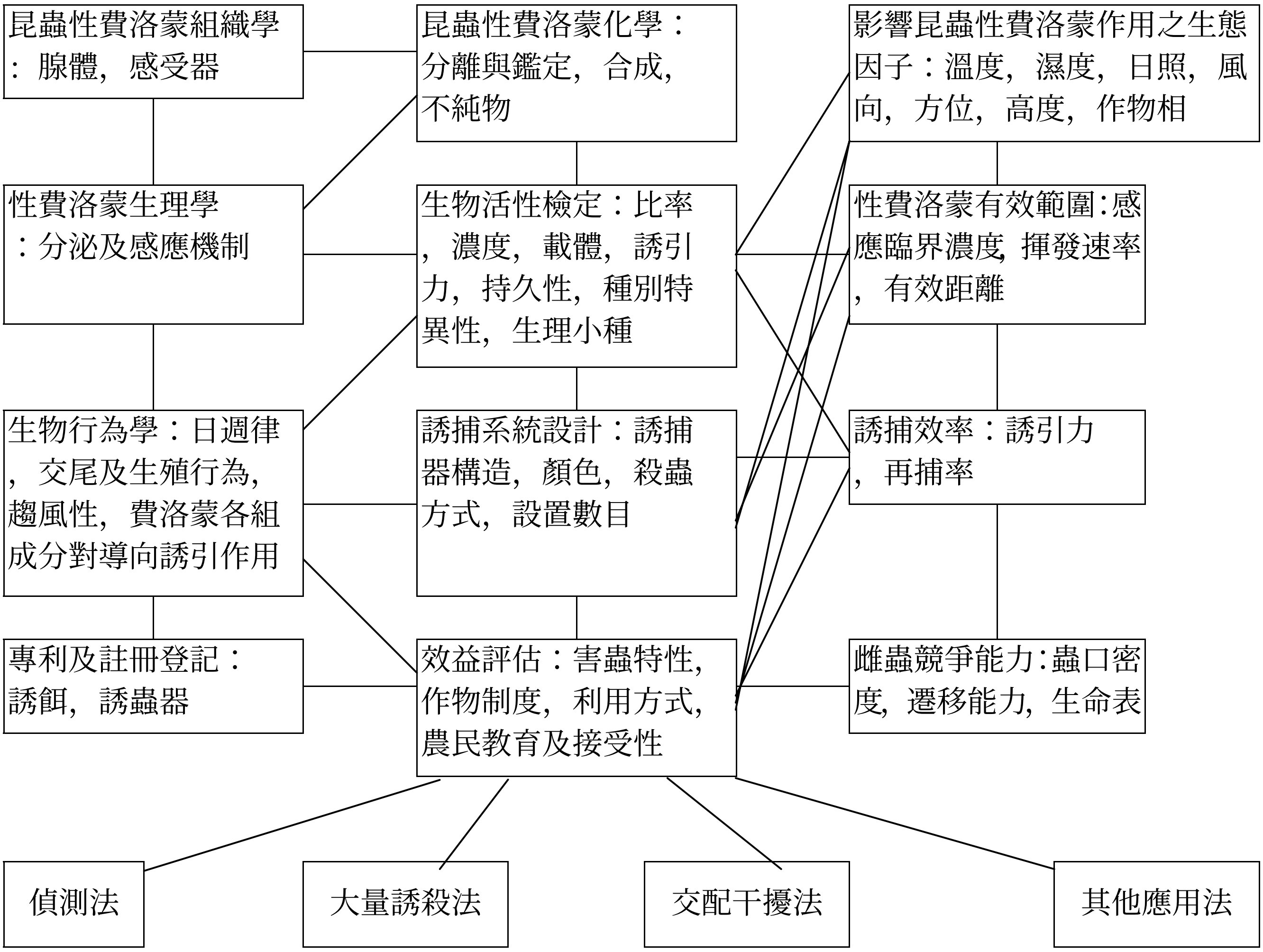
properties should play more important and successful role in plant protection and quarantine that will enhance rational use of insecticides, and promote the quality of environmental ecology.

（Key words: sex pheromones, insect pest management, Taiwan）

圖一爲 Excell 檔



圖二、昆蟲或動物中具傳訊作用之化學物質之流程圖。
Fig. 2. A flowsheet of the role of chemicals used for communication in insects and other animals.



圖三、昆蟲性費洛蒙基礎及應用研究有關科目之關聯圖。

Fig.3. The profile for basic and applied studing on insect sex pheromones and related chemicals.

表一、昆蟲性費洛蒙與殺蟲劑之特性比較

Table 1. Comparison of characteristics of sex pheromones and insecticides

特性	性費洛蒙	殺蟲劑
毒性	低	高
選擇性	高	低
安全性	高	低
生物活性與持效性	強與長	弱與短
抗藥性	不易產生抗藥性	易產生抗藥性
每公頃使用成本		中－高
密度偵測	低	
大量誘殺	低	
交配干擾	高	
使用效果	需配合其他防治法	可單獨使用
施用器具	特殊誘蟲器具	一般噴藥器械
生產設備	簡單且廢液量少	複雜需有廢液處理設備
生產成本	高	高
生產時間	長	短
每批生產量	幾克至百克	噸
農民接受性	需輔導	已有使用經驗

表二、台灣重要昆蟲的費洛蒙成分及其類似物一覽表

Table 2. List of pheromone components and related chemicals of some important insects in Taiwan

昆蟲種類	費洛蒙組成份	比例	參考文獻
家蠶 silkworm moth *Bombyx mori*	(1)(E,Z)-10,12-hexadecadienol(bombykol) (2)(E,Z)-10,12-hexadecadienal(bombykal) (3)(E,E)-10,12-hexadecadienol		Butenandt et al. (1959); Kasang et al. (1978a); Kasang et al. (1978b)
甘藷麥蛾 potato leaf-folder *Brachmia macroscopa*	(1)(E)-11-hexadecenyl acetate		Hirano et al. (1976)
棉紅鈴蟲 pink bollworm *Pectinophora gossypiella*	(1)(Z,Z)-7,11-hexadecadienyl acetate (2)(E,Z)-7,11-hexadecadienyl acetate	(1)/(2)=1/1	Hummel et al. (1973); Bierl et al. (1974)
麥蛾 angoumois grain moth *Sitotroga cerealella*	(1)(Z,E)-7,11-hexadecadienyl acetate		Vick et al. (1974)
台灣松毛蟲 pine caterpillar *Dendrolimus punctatus*	(1)(Z,E)-5,7-dodecadienol (2)(Z,E)-5,7-dodecadienyl acetate		Anonymous (1979)
甜菜夜蛾 beet armyworm *Spodoptera exigua*	(1)(Z,E)-9,12-tetradecadienyl acetate (2)(Z)-9-tetradecenol (3)(Z)-9-tetradecenyl acetate (4)(Z,Z)-9,12-tetradecadienyl acetate	(1)/(2)=5/4,10/1,or(1)/(3)=2/1,(4)for close-range stimulant	Brady & Ganyard (1972); Mitchell & Doolittle (1976); Tumlinson et al. (1981); Persoons et al. (1981); Mitchell et al. (1983); Cheng et al. (1985); Yen et al.(1988)
斜紋夜蛾 tobacoo cutworm *Spodoptera litura*	(1)(Z,E)-9,11-tetradecadienyl acetate (2)(Z,E)-9,12-tetradecadienyl acetate	(1)/(2)=10/1	Tamaki et al. (1973); Yushima et al. (1974); Chang (1977); Chiu & Chien (1979); Lo et al. (1988)
番茄夜蛾、玉米穗蟲 tomato fruit worm *Helicoverpa armigera*	(1)(Z)-11-hexadecenal (2)(Z)-9-hexadecenal	(1)/(2)=1000/32,100/1to100/12, 9/1	Piccardi et al. (1977); Nesbitt et al.(1979, 1980a); Kehat et al.(1980); Yeh & Lee (1986)
蕪青夜蛾 common cutworm, turnip moth *Agrotis fuscosa (segetum)*	(1)(Z)-5-decenyl acetate (2)(Z)-7-decenyl acetate	(1)/(2)=1/9	Wakamura (1980); Kozai & Wakamura (1982)
球菜夜蛾 black cutworm *Agrotis ipsilon*	(1)(Z)-7-dodecenyl acetate (2)(Z)-9-tetradecenyl acetate	(1)/(2)=5/1,3/1	Hill et al. (1979)
擬尺蠖	(1)(Z)-7-dodecenyl acetate	(1)/(2)=90.4/9.6,90/	Berger (1966); Bjostad et al.

cabbage looper *Trichoplusia ni*	(2)dodecyl acetate (3)(Z)-7-tetradecenyl acetate	10or(1)/(3)= 27/1	(1980)
二化螟 rice stem borer, *Chilo suppressalis*	(1)(Z)-11-hexadecenal (2)(Z)-13-octadecenal (3)(Z)-9-hexadecenal	(1)/(2)=5/1or(1)/(2)/(3)=81/10/8	Nesbitt et al. (1975); Ohta (1976)
甘蔗紫螟，水稻大螟 sugarcane pink borer purple stem borer *Sesamia inferens*	(1)(Z)-11-hexadecenyl acetate		Nesbitt et al. (1976)
甘蔗黃螟 sugarcane grey borer *Tetramoera schistaceana*	(1)(Z)-9-dodecenyl acetate		Anonymous (1978)
葡萄螟蛾 Vine leaf moth *Sparganothis pilleriana*	(1)(E)-9-dodecenol (2)(E)-9-dodecenyl acetate		Saglio et al. (1976)
粉斑螟蛾 almond moth *Ephestia cautella*	(1)(Z,E)-9,12-tetradecadienyl acetate (2)(Z)-9-tetradecenyl acetate (3) (Z,E)-9,12-tetradecadienol	(1) major attractant, (2) no attractant but synergist, (3) inhibitor	Kuwahara et al.(1971b); Brady et al.(1971); Brady (1973); Chow et al. (1975); Read & Haines (1976); Read & Beevor (1976); Hoppe & Levinson (1979)
茶斑螟蛾 tabacco moth *Ephestia elutella*	(1)(Z,E)-9,12-tetradecadienyl acetate		Brady and Nordlund (1971)
印度穀蛾 Indian meal moth *Plodia interpunctella*	(1)(Z,E)-9,12-tetradecadienyl acetate (2)(Z,E)-9,12-tetradecadienol	(1)/(2)=4/6	Kuwahara et al. (1971b); Brady et al. (1971); Chow et al. (1975); Coffelt et al. (1978); Hoppe & Levinson (1979); Levinson & Buchelos (1981); Vick et al.(1981)
地中海粉螟 Mediterraneun flour moth *Anagasta kuehniella*	(Z,E)-9,12-tetradecadienyl acetate		Brady et al. (1971); Kuwahara et al. (1971a)
亞洲玉米螟 Asian corn borer *Ostrinia furnacalis*	(1)(Z)-12-tetradecenyl acetate (2)(E)-12-tetradecenyl acetate (3)tetradecyl acetate (4)hexadecyl acetate	(1)/(2)=3/2 in Japan,(1)/(2)=47/53 in China, (1)/(2)/(3)/(4) =38/27/33/2, 75/25/0/0	Ando et al.(1980); Klun et al.(1980); Cheng et al.(1981) :Yeh et al.(1989): Hwang et al.(1990)
楊桃花姬捲葉蛾	(1)(Z)-8-dodecenyl acetate	(1)/(2)=1/0 or 1/1	Ando et al. (1977);

carambola fruit borer *Eucosma notanthes*	(2)(Z)-8-dodecenol		Hwang et al. (1987, 1996, 2000); Hwang & Hung (1994): Hung et al. (1999, 2001)
粗腳姬捲葉蛾，荔枝果蛾 litchi fruit borer *Cryptophlebia ombrodelta*	(1)(Z)-8-dodecenyl acetate		Ando et al. (1975) ; Hwang et al. (1987)
僞蘋果蛾 false codling moth *Cryptophlebia leucotreta*	(1)(E)-8-dodecenyl acetate (2)(Z)-8-dodecenyl acetate	(1)/(2)=1/1,70 /30 to 30/70	Persoons et al. (1976a,1977); Angelini et al.(1981)
東方果蛾、桃折心蟲 oriental fruit moth *Grapholita molesta*	(1)(Z)-8-dodecenyl acetate (2)(E)-8-dodecenyl acetate (3)(E)-8-dodecenol (4)dodecanol	(1)/(2)/(3)/(4)=100/7 /30/6 or(1)/(2)=92/8	Roelofs et al. (1969); Carde et al. (1979); Chow et al. (1979)
蘋果蠹蛾(檢疫害蟲) codling moth *Laspeyresia pomonella*	(1)(E,E)-8,10-dodecadienol		Roelofs et al.(1971); Beroza et al.(1974)
荔枝黃斑小捲葉蛾 grape vine moth *Lobesia aelopa*	(1)(E,Z)-7,9-dodecadienyl acetate		Roelofs et al. (1973)
番石榴櫛角捲葉蛾 eye-spotted budmoth *Spilonota rhothia*	(1)(Z)-8-tetradecenyl acetate		Arn et al. (1975,1982)
茶姬捲葉蛾 smaller tea tortrix *Adoxophyes privatans spp.*	(1)(Z)-9-tetradecenyl acetate (2)(Z)-11-tetradecenyl acetate (3)(E)-11-tetradecenyl acetate (4)10-methyl dodecyl acetate	(1)/(2)/(3)/(4)=63/31 /4/2, 47/50/1/2, 30-70/70-30/ 1-40/20-200	Tamaki et al. (1971, 1979,1980); Hsiao (1990)
茶捲葉蛾 tea tortrix *Homona magnanima*	(1)(Z)-11-tetradecenyl acetate (2)(Z)-9-dodecenyl acetate (3)11-dodecenyl acetate	(1)/(2)/(3) =30/3/1,80/10/10,80 /20/0	Noguchi et al. (1979); Hsiao (1998)
小菜蛾 diamondback moth *Plutella xylostella*	(1)(Z)-11-hexadecenyl acetate (2)(Z)-11-hexadecenal (3)(Z)-11-hexadecenol	(1)/(2)/(3)=1/1 /0 to 2/3/0, 49.5/49.5 /1	Tamaki et al. (1977); Chow et al. (1977); Koshihara et al. (1978); Ando (1979); Chien & Chiu (1986, 1987)
荔枝細蛾 litchi fruit borer *Conopomorpha sinensis*	(1)E,Z,Z-4,6,10-hexadecatrienyl acetate (2)E,E,Z-4,6,10-hexadecatrienyl acetate (3)E,Z,Z-4,6,10-hexadecatrien-1-ol (4)E,E,Z-4,6,10-hexadecatrien-1-ol	(1)/(2)/(3)/(4) /(5)=40/60/4/6/10 or 40/60/0/0/0	Beevor et al. (1986): Hwang el al. (1996)

	(5)n-hexadecyl alcohol		
台灣豆金龜(藍豔豆金龜) Taiwan beetle *Popillia taiwana* (*P. indigonacea*)	(1)(R,Z)-5-(1-decenyl)dihydro-2-(3H)-furanone (2)2-phenyl ethyl propionate (3)eugenol		Tumlinson et al. (1977); Klein et al. (1981); Chow (1986)
椰子犀角金龜，台灣兜蟲 Rhinoceros beetle *Oryctes rhinoceros*	(1)ethyl2,2-dimethyl-3-(2-methylpropyl)cyclopropanecarboxylate (2)des-N-morphinan (3)Ethyl chrysanthemumate		Barber et al. (1971); Maddison et al.(1973); Vander Meer et al.(1979)
甘蔗櫛叩頭蟲，金針蟲 sugarcane wireworm *Melanotus tamsuyensis*	(1)E,E-9,11-dodecadienyl=butynate (2)E,E-9,11-dodecadienyl=hexanoate	(1) /(2)=96.7/ 3.3	Hwang et al. (unpublished)
小紅鰹節蟲 khapra beetle *Trogoderma granarium*	(1)(Z)-14-methyl-8-hexadecenal (2)(E)-14-methyl-8-hexadecenal	(1)/(2)=92/8	Cross et al. (1976); Levinson et al. (1978); Silverstein et al. (1980); Levinson & Mori (1980)
煙甲蟲 cigarette beetle, Japan *Lasioderma serricorne*	(1)4,6-dimethyl-7-hydroxy-nonan-3-one (2)2,3-cis-2,3-dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-oxobutyl)-4H-pyran-4-one (3)2,3-cis-2,3-dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-hydroxybutyl)-4H-pyran-4-one		Chuman et al. (1979); Chuman, (1981); Chuman et al.(1983)
煙甲蟲 cigarette beetle,Germany *Lasioderma serricorne*	(1)2,6-diethyl-3,5-dimethyl-3,4-dihydro2H-pyrane (2)2,3-cis-2,3-dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-oxobutyl)-4H-pyran-4-one (3)2,3-cis-2,3-dihydro-3,5-dimethyl-2-ethyl-6-(1-methyl-2-hydroxybutyl)-4H-pyran-4-one		Levinson et al.(1981); Chuman et al.(1983)
穀蠹 lesser grain borer *Rhyzopertha dominica*	(1)1-methylbutyl(E)-2-methyl-2-pentenoate (dominicalure 1) (2)1-methylbutyl(E)-2,4-dimethyl-2-pentenoate (dominicalure 2)		Khorramshahi & Burkholder (1981); Williams et al. (1981)
擬穀盜 red flour beetle *Tribolium castaneum*	(1)4,8-dimethyldecanal		Suzuki & Sugawara (1979)
扁擬穀盜 confused flour beetle	(1)4,8-dimethyldecanal (2)1-pentadecene		Keville & Kannowski (1975)

Tribolium confusum	(3)hexadecane (4)1-heptadecene		
角胸粉扁蟲 rusy grain bettle *Cryptolestes ferrugineus*	(1)(E,E)-4-8-dimethyl-4,8-decadien-10-olide (ferrulactone I) (2)(3Z,11S)-3-dodecen-11- olide (ferrulactone II)		Borden et al. (1979); Wong et al.(1983)
小角胸粉扁蟲 smaller rusy grain bettle *Cryptolestes turcicus*	(1)(Z,Z)5,8-tetradecadien-13-olide		Millar et al.(1983)
鋸胸粉扁蟲 saw-toothed grain bettle *Oryzaephilus surinamensis*	(1)(Z,Z)3,6-dodecadien-11-olide (2)(Z,Z)3,6-dodecadienolide (3)(Z,Z)5,8-tetradecadien-13-olide		Pierce et al.(1984)
米象 rice weevil *Sitophilus oryzae*	(1)(4S,5R)-4-methyl-5-hydroxy-3-hepta none (sitophilure)		Schmuff et al.(1984)
玉米象 maize weevil *Sitophilus zeamais*	(1)(4S,5R)-4-methyl-5-hydroxy-3-hepta none(sitophilure)		Schmuf et al.(1984)
綠豆象 azuki bean weevil *Callosobruchus chinensis*	(1)a mixture of methyl- branched saturated hydrocarbons (2)(E)-3,7-dimethyl-2-octene-1,8-dioic acid	Mixture of (1) and (2) elicits copulatory attempt of male	Tanaka et al. (1981); Tanaka et al. (1982)
甘藷蟻象 sweet potato weevil *Cylas formicarius*	(1)Z-3-dodecenyl-1-ol(E)-2-butenoate		Heath et al. (1986); Hwang et al.(1989,1990)
黃條葉蚤 striped leaf beetle *Phyllotreta striolata*	(1)allyl isothiocyanate (mustar oil)		Feeny et al., (1970); Burgess & Wiens (1980); Hung & Hwang (2000)
松斑天牛 pine sawyer *Monochamus alternatus*	(1) α -pinene (2) β -pinene (3)ethanol		Ikeda et al., (1980); Hwang et al. (2000)
東方果實蠅 oriental fruit fly *Bactrocera dorsalis*	(1)1,2-dimethoxy-4(2-propenyl)-phenol (methyl eugenol)		Howlett (1912,1915); Steiner (1952,1965)
瓜實蠅 melon fly *Bactocera cucurbitae*	(1)4-(4-acetoxyphenyl)-2-butanone (cuelure)		Beroza et al. (1960)
家蠅 house fly *Musca domestica*	(1)(Z)-9-tricosene (2)4,8-dimethylheptacosane (3)13-methylnonacosane		Carlson et al. (1971); Uebel et al. (1976)
德國蜚蠊	(1)3,11-dimethyl-2-nonacosanone	(1)/(2)=33/1.7	Nishida et al.

German cockroach *Blattella germanica*	(2)29-hydroxy-3,11-dimethyl-2-nonacosanone		(1974,1976,1979)
美洲蜚蠊 American cockroach *Periplaneta americana*	(1)(1Z,5E)-1,10(14)-diepoxy-4(15),5-germacradien-9-one		Persoon et al.(1976b,1979,1982); Talman et al.(1978); Adams et al.(1979); Yang et al. (1998)
芒果赤圓介殼蟲，加州紅圓介殼蟲 California red scale *Aonidiella aurantii*	(1)3-methyl-6-isopropenyl-9-decenyl acetate (2)(Z)-3-methyl-6-isopropenyl-3,9-decadienyl acetate		Roelofs et al. (1977,1978); Gieselmann et al.(1980)
桔黃圓介殼蟲 yellow scale *Aonidiella citrana*	(1)(E)-3,9-dimethyl-6-isopropyl-5,8-decadienyl acetate		Gieselmann et al. (1979)
桃白介殼蟲，梨圓介殼蟲 white peach scale, Florida red scale *Pseudaulacaspis pentagona*	(1)(Z)-3,9-dimethyl-6-isopropenyl-3,9-decadienylpropanoate		Heath et al. (1979)
桔粉介殼蟲 citrus mealybug *Planococcus citri*	(1)(1-R-cis)(＋)-2,2-dimethyl-3-isopropenyl-cyclobutyl-methyl acetate		Bierl-Leonhardt et al.(1981): Dunkelblum et al. (1987); Hwang (1988)
桑粉介殼蟲 comstock mealybug *Pseudococcus comstocki*	(1)2,6-dimethyl-1,5-heptadien-3-yl acetate		Bierl-Leonhardt et al.(1980); Negishi et al.(1980b)
桃蚜 green peach aphid *Myzus persicae*	(1)(E)-β-farnesene		Bower et al.(1972); Edwards et al.(1973) Hwang et al.(1996)
蜜蜂 honey bee *Apis mellifera*	(1)(E)-9-oxo-2-decenoic acid (2)(E)-9-hydroxy-2-decenoic acid		Butler and Fairey (1964); Blum, et al.(1971)
褐狗壁蝨 brown dog tick *Rhipicephalus sanguineus*	(1) 2,6-dichlorophenol (2) 2,6-di-tert-butyl-4-methyl phenol		Berger (1972); Chow et al.(1975)

表三、台灣於1994年推廣利用性費洛蒙誘殺防治害蟲之種類與面積

Table 3. Area and species of sex pheromones used in Taiwan in 1994

作物	斜紋夜蛾		甜菜夜蛾		甘藷蟻象		茶姬捲葉蛾		楊桃花姬捲葉蛾	
	公頃數	誘餌數	公頃數	誘餌數	公頃數	誘餌數	公頃數	誘餌數	公頃數	誘餌數
落花生與大豆	13,250	79,500	2,000	48,000						
蔬菜	3,393	48,438	2,123	61,044						
花卉	700	26,702	700	25,689						
草莓	457	21,936								
甘藷					1,500	180,000				
茶樹							300	52,500		
楊桃									220	8,800
總計	17,800	176,576	4,823	134,733	1,500	180,000	300	52,500	220	8,800

表四、性費洛蒙與傳統殺蟲劑之毒理比較

Table 4. Comparison of the toxicology of some sex pheromones with that of a commonly used insecticide, azinphos-methyl (Gusathion)

試驗項目	動物種類	Z8-12Ac[1)] E8-12Ac	Z7Z11-16Ac[2)] Z7E11-16Ac	Azinphos-methyl (谷速松)
口服急毒性 LD_{50}	大鼠	NOEL>17.1 g/kg	NOEL>15 g/kg	M:16 mg/kg F:13.5 mg/kg
皮膚急毒性 LD_{50}	大鼠	NOEL>20.0 g/kg	－	M:455 mg/kg F:220 mg/kg
呼吸急毒性 LC_{50}	大鼠	NOEL=74.7 mg/l	NOEL>3.3 mg/l	M:69 mg/kg F:79 mg/kg
皮膚刺激性	白兔	微刺激性	無作用	－
眼刺激性	白兔	無作用	無作用	－
Ames 致變異性	－	無作用	無作用	無作用
90天亞慢毒性	大鼠	－	NOEL>3000 ppm	抑制腦鹼酯酶活性
90天亞慢毒性	狗	－	NOEL>3000 ppm	降低腦鹼酯酶活性
口服急毒性	野鴨	－	LD_{50}>10 g/kg	－
96小時急毒性	鱒魚	－	LC_{50}=540 ppm	－

1)桃折心蟲或東方果蛾及楊桃花姬捲葉蛾性費洛蒙成分。

2)棉紅鈴蟲性費洛蒙成分。