出國報告（出國類別：開會）

參加「第 9 屆小菜蛾和其他十字花科害蟲管理國際研討會(Ninth International Conference on Management of the Diamondback Moth and Other Crucifer Insect Pests) 」

服務機關：行政院農業委員會農業藥物毒物試驗所
姓名職稱：黃莉欣研究員、陳富翔助理研究員、楊尚唯助理研究員
派赴國家：柬埔寨金邊
出國期間：**112** 年 **05** 月 **01** 日至 **05** 月 **06** 日
報告日期：**112** 年 **7** 月 **19** 日

摘要

第 9 屆小菜蛾和其他十字花科害蟲管理國際研討會於柬埔寨金邊舉辦，由亞蔬-世界蔬菜中心主辦，柬埔寨皇家農業大學及本所協辦，供各國研究人員分享與交流小菜蛾及其他十字花科蔬菜害蟲之防治研究成果，內容涵蓋防治資材開發、抗藥性管理、天敵研究、IPM 實施方式、氣候變遷影響、以及對防治小菜蛾的分子生物學研究模式等。本屆共 18 國 77 學者現場或線上參加，本所農藥應用組黃莉欣研究員、資材研發組陳富翔助理研究員及楊尚唯助理研究員現場與會，分別發表 3 篇海報論文。參加本次研討會獲知各國的研究進展與成果，也提供了不同應用防治技術，可作為未來小菜蛾和其他十字花科害蟲管理防治技術改進之參考，也是參加本研討會的主要目的。

目 次

壹、前言及目的

十字花科蔬菜 (Cruciferous vegetables)是我國重要的經濟作物之一，包含甘藍(高麗菜)、包心白菜、小白菜、青江白菜、油菜、芥藍、芥菜、花椰菜、青花菜、蘿蔔等我國餐桌常見的佳餚，是對人類健康至關重要的重要經濟蔬菜。這些營養豐富的蔬菜為人類提供必要的維生素和礦物質—尤其是維生素 A 和 C、鐵、鈣、葉酸及膳食纖維等。十字花科植物還能夠預防不同類型的癌症，栽培成本低廉，對低度開發國家至已開發國家來說皆是不能或缺的重要作物。十字花科既然是廣為栽培的作物，其病蟲害亦是人們關注的焦點，其中最嚴重受人關注的害蟲及為本次研討會的主角：小菜蛾 [diamondback moth (DBM), *Plutella xylostella*]。

小菜蛾屬於鱗翅目 (Lepidoptera) 菜蛾科 (Plutellidae)，在台灣的俗名為吊絲蟲，是一種專食十字花科作物的害蟲。牠們生長快速，族群量龐大，在臺灣一年發生15 - 20代，繁殖力強，飛行能力雖不強，但可隨著氣流散布。幼蟲只啃食十字花科植物葉片，造成葉菜類商品價值下降。也由於牠們的繁殖力強，防治困難，農民用藥頻繁，容易產生抗藥性族群，現今各國對防治小菜蛾的問題仍投入相當多的研究，包括防治資材的開發與應用。而葉蚤類 (flea beetle) 的害蟲如黃條葉蚤 (Stripped flea beetle, *Phyllotreta striolata*) 更是蘿蔔及十字花科小葉菜類的頭號害蟲，在高溫期設施栽培或有機栽培的田區中甚是嚴重，由於成蟲善跳躍，幼蟲又躲在地底下，以致於農藥難以接觸而進行防治，這些問題皆是十字花科作物生產時的重大阻礙。

「國際小菜蛾及其他十字花科害蟲研究 (International Working Group on DBM and other Crucifer Insects)」工作團隊為一個包含全球致力於十字花科害蟲研究與管理之研究人員的非正式組織。該研究團隊自1985年至今每4 - 6年舉辦一次國際研討會，並集合全球專家在一起討論小菜蛾及其他十字花科害蟲的管理問題，其中第一屆和第二屆研討會於1985年和1990年由亞洲蔬菜研究與發展中心 (Asian Vegetable Research and Development Center, AVRDC) 在臺灣舉辦。第三屆研討會於1996年由馬來西亞農業研究與發展所 (Malaysian Agricultural Research and Development Institute) 在吉隆坡舉辦，第四屆研討會於2001年在澳大利亞舉辦，第五屆研討會於2006年由中國農業科學院在北京組舉辦，第六屆研討會於2011年由亞蔬-世界蔬菜中心 (AVRDC – the World Vegetable Center) 在泰國舉辦，第七屆研討會於2015年由邦加羅爾農業科學大學 (University of Agricultural Sciences, Bangalore) 舉辦，第八屆小

菜蛾及其他十字花科昆蟲害蟲管理國際研討會於2019年由亞蔬-世界蔬菜中心舉辦在臺灣善化總部。而本屆為第九屆於2023 (今) 年由亞蔬-世界蔬菜中心主辦，柬埔寨皇家農業大學與本所協辦，在柬埔寨金邊舉辦，因近年該中心有許多推廣計畫將於柬埔寨應用，因此特選本地進行研討會辦理地點，本次會議參與人員經主辦單位統計共有現場出席55人及線上參與22人共計77人，為來自18個國家 (澳大利亞、孟加拉、柬埔寨、喀麥隆、中國、衣索比亞、斐濟、加納、印度、肯亞、韓國、馬來西亞、菲律賓、西班牙、台灣、坦尚尼亞、泰國、美國) 的研究者參與。

本次會議主軸在於與各國研究人員分享各自對於小菜蛾及其他十字花科蔬菜害蟲之各種防治研究。目前各國皆著重於綜合害物管理 (integrated pest management, IPM) 來進行蟲害管理朝化學農藥減量目前邁進，我國亦於107年提出「化學農藥十年減半」政策，藉由參與本次國際研討會，除了分享我國在十字花科作物上防治小菜蛾非化學農藥資材的研發過程，亦可蒐集各國對於防治十字花科害物的各種研究，包括資材開發、天敵研究、IPM實施方式、氣候變遷影響以及其他各種有關小菜蛾或其他十字花科害物的研究等，做為未來研究參考。並於此次會議與各國專家接觸，為未來國際合作奠定良好的基礎。

貳、行程紀要

日　期	行　　程
05 月 01 日(週一)	去程。搭程 08:45 長榮航空，直達柬埔寨首都金邊，當地時間 11:30 落地，約 13:00 完成通關手續，並由住宿飯店轉介車輛接駁至 Himawari hotel (葵花大酒店) 住宿，登記入住時約 14:30。
05 月 02 日(週二)	報到並參加「第 9 屆小菜蛾和其他十字花科害蟲管理國際研討會」開幕式及團體照。上午場為主辦協辦單位致詞，並由第一位講者發表論文。下午延續上午之主題，由其他 8 位學者發表 9 篇論文。中間休息時間由陳富翔助理研究員進行海報發表。
05 月 03 日(週三)	會議第二天，主題為執行 IPM 相關之研究，11 位學者發表論文，上午場休息時間由黃莉欣研究員進行海報發表。下午演講主題為非化學防治方法，由 3 位學者發表論文。

日　期	行　　程
05 月 04 日(週四)	會議第三天，全天主題皆為延續第二天的 IPM 相關研究，分別由亞洲、非洲及澳洲的 16 位學者發表相關研究。下午場休息時間由楊尚唯助理研究員進行海報發表。
05 月 05 日(週五)	會議第四天，第一場仍為 IPM 之主題，隨後 3 位學者發表基因層次相關之研究。大會於 12:00 圓滿結束，並宣布下次會議預定地點為非洲，下午午餐後為學者自由交流時間。
05 月 06 日(週六)	回程。由住宿飯店轉介接駁車至金邊機場，搭乘 12:35 長榮航空直航臺灣，約 17:15 抵達桃園機場。

參、參加「第 9 屆小菜蛾和其他十字花科害蟲管理國際研討會」內容紀要

一、5 月 2 日上午 09:00 於金邊 Himawari hotel (葵花大酒店) 報到註冊，10:00 會議準時開幕，先由亞蔬首席昆蟲學家 Dr. Srinivasan Ramasamy (Srini)致詞介紹會議歷史，再由亞蔬主任 Dr. Marco Wopereis (Macro)以視訊方式致歡迎詞，接著由亞蔬副主任林彥蓉博士說明害蟲管理的重要性以減少化學農藥的使用，最後由協辦單位柬埔寨皇家農業大學校長 Dr. Ngo Bunthan 致詞，說明柬埔寨用藥也是很普遍，希望藉由研討會來推進當地害蟲管理。正式開始論文發表，第一節主題是有關十字花科作物上害蟲與其天敵其寄主抗性與化學生態學的研究，首先由昆士蘭大學 (澳洲) 的 Dr. Furlong 發表陷阱作物對小菜蛾產卵效果之影響，並利用水楊酸處理加強其產卵意願。午餐過後，接著由 3 位學者連續發表 3 篇有關於非洲在十字花科作物上實施推拉理論 (push-pull theory) 的研究。此 3 位學者分別是國際昆蟲生理生態研究中心 (International Centre of Insect Physiology and Ecology, ICIPE) 的 Dr. Chidawanyika 介紹在肯亞執行的驗證試驗結果，再由亞蔬坦薩尼亞中心的 Dr. Boniface 介紹在坦薩尼亞對小菜蛾及蚜蟲執行的試驗結果，最後是 ICIPE 的 Dr. Niassy 視訊介紹烏干達執行的狀況。3 位學者皆利用 *Desmodium* 屬植物做為驅蟲植物，並以產量及品質驗證。接著由中國學者 Xiao 報告黃條葉蚤幼蟲與成蟲使用相同味覺器官之研究後，進入海報/休息時間。由陳富翔助理研究員現場講解「臺灣研發小菜蛾性費洛蒙誘捕系統之研究 [The study and development of mass trapping system for sex pheromone of *Plutela xylostela* (Lepidoptera: Plutellidae)

in Taiwan]」海報內容，獲得熱烈迴響，可見費洛蒙受到各國研究人員重視。接著回到口頭論文發表，由印度 ATGC 公司的 Dr. Gorantla 連續發表 2 篇費洛蒙奈米材料緩釋技術、交配干擾產品及各種使用方法，也引起現場多人興趣。後續由西班牙學者 Dr. Badenes-Perez 發表硫配醣體 (glucosinolates) 對小菜蛾及紋白蝶產卵、取食感受性的研究，結束了第一節。第二節的主題是有關執行綜合害物管理 (integrated pest management, IPM) 的研究，但先由國際農業生物科學中心 (Centre for Agriculture and Bioscience International, CABI) 馬來西亞的學者 Dr. Faheem 介紹他們所開發的國際生物農藥資訊系統，用於推廣生物農藥，與本所建立植物保護資訊系統及生物農藥檢索平台立意相同，不過該網站只引介英語系國家之資訊。在 Dr. Faheem 報告完後結束第一天的會議。

二、5 月 3 日研討會第 2 日，有進行部分議程變更。上午場延續前一日的 IPM 主題，由亞蔬首席昆蟲學家 Srini 發表在臺灣實驗室內測試鱗翅目蘇力菌對黃條葉蚤效果之研究，接著由亞蔬中南亞中心的學者 Dr. Ravishankar、總部的 Dr. Sotelo 發表在印度及柬埔寨執行 IPM 之田區其成本收益比較之研究，皆顯示 IPM 優於非 IPM 田區。上午場海報/休息時間，由黃莉欣研究員現場講解「臺灣使用環境風險商數 (EIQ) 導入 IPM 以減少農藥使用風險 (Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of pesticide use in Chinese Cabbage Production in Taiwan)」海報內容，向與會研究人員闡述我國執行 IPM 工作，並以 EIQ 評估農藥的使用風險來做風險管控的研究。休息過後由 3 為美國的學者介紹喬治亞州、佛羅里達州對小菜蛾管理之研究，包括藥劑篩選、寄生蜂調查等。接著進入第三節主題，有關殺蟲劑抗性之研究，由菲律賓的 Dr. Bautista 視訊發表調查小菜蛾腸道中的細菌，發現一些細菌可協助小菜蛾分解殺蟲劑，進而協助小菜蛾對殺蟲劑產生抗性。下午場，由 Dr. Nand 發表在斐濟群島的小菜蛾抗藥性管理 (insecticide resistance management, IRM) 議題，藉由導入多種生物資材進行斐濟群島的小菜蛾抗藥性管理。接著由馬來西亞博特拉大學農學院的 Ishadi 研究者，發表小菜蛾對賜諾殺抗性遺傳研究，研究顯示小菜蛾對賜諾殺抗性遺傳，應藉由調整低劑量施用賜諾殺的習慣，以減少抗性小菜蛾族群的篩選。再由印度的 Dr. Murugan 線上發表小菜蛾與斜紋夜蛾對賽安勃抗性分析研究，目前研究指出，賽安勃在防治小菜蛾上已有

抗性產生，但對於斜紋夜蛾仍有效果，但仍要考慮未來對斜紋夜蛾的抗藥性風險產生而調整田間施藥方法，中間穿插 CABI 的 Dr. Sivapragasam 發表有關於緬甸利用友善物質執行 IPM 之研究，結果顯示 IPM 在當地具有潛力。接下來為第四個主題，係有關生物性及非化學性防治方法的研究，由印度、迦納及孟加拉等 3 位學者視訊介紹當地研發生物性防治資材的研究，其中印度泰米爾納德大學的 Dr. Selva Rani 發表有關 chitosan 防治資材廣受討論。最後由 ICIPE 的 Dr. Niassy 發表在多層次花園 (wonder multistorey garden, WMSG)使用黑水虻肥料比較與純用氮磷鉀肥料效果相當之研究，結束第二天的會議。

三、5 月 4 日研討會第三天，整天都是第四節有關生物性及非化學性防治方法管理十字花科害蟲的研究。首先由今年曾來本所訪問的印度泰米爾納德大學植物保護研究中心主任 Dr. Shanthi 連續發表兩種生物性資材的開發研究，第一篇與前一天同大學學者研究類似的 chitosan O Arginie (CS-O-Arg) 其製劑與效果；另一篇則是大花田菁萃取物製劑與效果研究，都有對小菜蛾不錯的防治效果。接著澳洲昆士蘭大學 Dr. Gurr 發表多層次地景對天敵活性的影響，及中國王樂韻博士發表其於澳洲時對半閉彎尾姬蜂在氣候變遷的研究。休息時間由柬埔寨學者進行海報發表當地小菜蛾抗藥性的研究。隨後當地 Dr. Soth 發表篩選 14 隻白殭菌屬的資材混用防治小菜蛾的結果研究、亞蔬的 Dr. Sopana Yule 發表內共生線蟲與黑殭菌、白殭菌等生物農藥混用防治黃條葉蚤的研究、泰米爾納德大學的 Dr. Ambethgarz 發表白殭菌的應用後，結束上午的議程。下午由澳洲昆蟲學界泰斗 Dr. Zalucki 介紹利用不同防治基準 (economic threshold)之防治策略評估其對小菜蛾管理的可行性，結果發現當小菜蛾密度高時，建議施用化學殺蟲劑控制蟲數，密度下降低後再釋放天敵彎尾姬蜂(*Diadegma semiclausum*)，另外依季節中斷栽培小菜蛾的寄主植物，結果顯示中斷栽培小菜蛾寄主植物 1 季，大大降低小菜蛾危害的比例，若再加入天敵的釋放，也大量減少化學殺蟲劑的使用頻度與施用量。接續著由印度學者 Dr. Nithya 視訊發表添加 chitosan 及酵母可增加白殭菌殺小菜蛾的效果之研究、印度學者 Dr. Kumar Sharma 視訊發表當地農民自製秘方的天然保護資材試驗效果、肯亞學者 Dr. Wangungu 視訊發表生態療法與化學防治無顯著差異等，下午場海報/休息時間。由楊尚唯助理研究員現場進行海報講解「兩個來自臺灣能有效防治小菜蛾的蘇力菌亞種 (The effectiveness of two subspecies of Bacilus thuringiensis collected from Taiwan against *Plutela xylostela*

(Linnaeus))」海報內容，現場反應熱絡，亦有馬來西亞農藥廠商想要引進本所研發之蘇力菌至當地防治抗藥性極高的吊絲蟲 (小菜蛾)。最後由 3 位非洲的學者 (衣索比亞、肯亞、喀麥隆) 發表生物農藥的效果，以及家禽肥料與化學肥料使用後對十字花科蔬菜產量及害蟲密度的研究，結束第三天的會議。

四、 5 月 5 日研討會第四天，先由澳洲昆士蘭大學博士候選人翁崧夏先生 (也是來自臺灣) 發表誘發植物氣味對寄生蜂行為影響的研究後，進入第五節以基因方法管理十字花科害蟲的主題。此主題先由南韓學者 Dr. Juil Kim 以視訊方式連續發表 2 篇論文，分別是 2 種小菜蛾寄生蜂彎尾姬蜂屬(*Diadegma fenestrale* 及 *Diadegma semiclausum*)與其 2 種共生病毒共演化的研究，及以恆溫環狀擴增法(Loop-mediated isothermal Amplification, LAMP)來發展鑑定前述 2 種小菜蛾寄生蜂的方法研究。最後由印度學者 Dr. Asokan 視訊發表以基因編輯(CRISPR/Cas9)技術，發展 RNAi 技術來防治小菜蛾之研究後，結束本次會議所有的論文發表。會議發表於當地時間 11:48 結束，由 Dr. Srini 總結，並勉勵各位學者繼續精進研究，最後宣布 4 年後的下一屆會議將在非洲舉行，地點可能選在肯亞或者坦桑尼亞。會議於 12:00 準時結束，會後本所與會人員和其他學者持續進行交流，午餐後為自由交流時間，本所與會人員與王樂韻博士交流研究非化學農藥防治主題與心得，並瞭解近年王博士致力於該國螳螂的生態研究。

肆、重要心得

一、 本次研討會為亞蔬-世界蔬菜中心主辦，目的在於為研究人員提供一個共同平台，並集合全球專家一起討論小菜蛾及其他十字花科害蟲的管理問題，來自各國的研究人員將分享近年在害蟲之生態學、寄主植物抗性、生物防治、殺蟲劑和十字花科作物抗蟲管理以及綜合害物管理方面的新發現。本次會議有來自亞洲、非洲、歐洲、北美和大洋洲 共 18 個國家的 77 位科學家與會。除了亞蔬的優秀專家群以外，亦有昆士蘭大學名譽教授 Dr. Myron Zalucki 帶領各位研究人員討論有關各種十字花科害蟲的防治研究及深入話題。本次的主題中，與本所 3 位與會人員相關的研究分別為：**十字花科害蟲及其天敵的昆蟲植物相互作用、寄主植物抗性和化學生態學、十字花科植物害蟲的抗藥性和管理：持續的挑戰、小菜蛾和其他十字花科植物害蟲：氣候變化帶來的全**

球挑戰、十字花科植物害蟲的生物和非化學管理方法、以及**持續採用 IPM 管理小菜蛾和其他十字花科植物害蟲的限制和機會**等。藉由了解各國人員的研究，並了解因地制宜的防治方法，著實給予與會人員開啟更多發想方向及研究動能。

二、本次活動第一個主題為有關十字花科作物上害蟲與其天敵其寄主抗性與化學生態學的研究，與陳富翔助理研究員研究主題相關，其中 3 位來自非洲的學者發表有關推拉理論在實際田間驗證的結果，皆顯示具有一定的防治效果。推拉理論主要是在田區中間設置驅蟲物質或植物，將害蟲**推出**田區，並在田區外圍設置吸引蟲的物質或植物，把害蟲**拉到**田區外面，並將其一網打盡。推拉理論是一種可用於 IPM 的工具，結合了讓行為改變的誘引/趨避物組合來處理害蟲的分布和數量。傳統的推拉策略主要是利用天然植物來執行，不使用化學物質來防治這些害物。他們的研究有一個共通點就是以 *Desmodium* 屬植物 (*D. uncinatum* 及 *D. intortum*) 做為驅蟲植物，將其與作物間作。試驗調查害蟲、天敵及產量與價值，顯示實施推拉理論有助於蟲害管理。推拉理論在我國並未有實際實施的案例，主要是因為我國農田大多為小田區，極少以間作來種植不同作物來維持單位面積的產量。但我們可研發化學傳訊素的防治資材，替代驅蟲或吸蟲作物，亦可能可以執行推拉理論，此部分可做為未來發展新型害蟲防治策略的參考。

三、昆士蘭大學的 Dr. Furlong 及其博士班研究生翁崧夏先生以化學生態學角度研究陷阱作物、小菜蛾、寄生蜂的交互作用，從這些基礎研究中，可以發想強化陷阱作物效果的可能實施方式，並釐清田間生態系中各種昆蟲在各種化學訊號中行為改變現象，可藉此做為未來研究方向，研發更多適合我國執行的非化學防治方法。

四、第一天下午印度 ATGC 公司的 Dr. Gorantla 發表兩篇有關費洛蒙產產品的研究論文，其中提出以多孔奈米材料作為費洛蒙緩釋之載具來延長費洛蒙的田間效期研究。緩釋材料的研究在本所研究雖已起步，然相關研究仍不多，多以現有材料進行測試，此研究方式可作為研究人員之借鏡，多孔奈米材料可納入未來研發標的，與會人員也有與印度 ATGC 公司的 Dr. Gorantla 交流該廠商的產品資訊，該公司有許多交配干擾的費洛蒙產品型態，可作為本所研發人員的參考。

五、本次會議唯一一個與其他研究不同的是由 CABI 的 Dr. Faheem 介紹該組織發展的 CABI BioProtection Protal，它是一種與本所開發的植物保護資訊系統相似的生物農藥查詢系統，除了生物農藥外，用戶也可在該系統查詢到天然資材等在國內或其他國家無須農藥登記之環境友善植物保護產品，雖然該系統目前只能整合英語系國家的相關產品資料，尚未拓展到全球的友善植物保護產品資訊彙整，但對於我國研究人員來說，該系統已將多國植物保護資訊統整，可作為資料蒐集的重要工具。

六、有關第二個主題 IPM，實際上 IPM 也是我國在化學農藥十年減半政策上重要的工具之一，本次有多位學者發表各國在實施 IPM 的研究，結果皆不約而同地探討實施 IPM 對產量及產值有明顯的助益，並且對於投入成本及回收利潤的結果是對農民有益的，希望藉由這樣的試驗及示範來增加農民執行 IPM 的意願，然而，這些研究大多著重於使用綠色 (環境友善) 資材及栽培管理措施的使用方式，並未針對監測田間害物發生狀況選擇最佳防治資材及介入時機進行探討。與會人員黃莉欣研究員發表的研究指出，執行 IPM 時害物監測與紀錄工作極為重要性，才能對防治時機與措施提出合理的防治決策，並導入環境風險商數 (EIQ) 的概念，讓研究人員了解所有的防治資材若在使用量未有相當的控制下，仍然具有一定的風險，例如礦物油，在良好的風險控管下執行 IPM，不僅能減少對環境的衝擊，也可以讓農民取得足夠的收益，達到農業永續的目標。

七、第三個主題是有關小菜蛾抗藥性議題之研究，學者們針對賜諾殺、賽安勃、剋安勃及氟大滅進行探討，目前在馬來西亞發現小菜蛾已對賜諾殺產生抗性，小菜蛾對賜諾殺屬於具有單一抗性控制因子的體染色體遺傳，在田間存在時間可能更長且進展更快，而單一因素的影響可能較多重抗性來得嚴重。因此，在抗藥性管理時應注意避免使用低劑量及無法接受的高劑量的使用，否則易造成產生抗藥性族群的風險。另外在印度也發現小菜蛾對賽安勃與也開始逐漸地產生抗藥性，但使用 DEM (diethyl maleate) 與 PBO (piperonyl butoxide)等協力劑，可降低小菜蛾對此藥的抗藥性發生，輪替使用不同作用機制的殺蟲劑可延緩抗藥性的發生。此表示小菜蛾的抗藥性問題在各國仍然持續發生，因此開發各種不同機制的小菜蛾藥劑則顯得十分重要，也包含非化學性的防治方式的使用，包含生物性防治資材 (蘇力菌、蟲生真菌) 或是化學傳訊素的應用等。

八、在第四個主題研發生物農藥及非化學防治小菜蛾方法方面，雖然該主題總共橫跨 3 天議程，不過與會人員認為最後一篇由翁崧夏先生發表的論文應與第一主題較為相關。各國研究人員在這主題中分享了許多生物農藥及非化學防治方法的研發，如殼聚醣 (chitosan)、白殭菌 (*Beauveria* sp.)、黑殭菌 (*Metarhizium* sp.)、萃取自苦楝 (neem)的印楝素、蘇力菌 (*Bacillus thuringiensis*)、蟲生線蟲、天然植物萃取物、天敵等對小菜蛾、黃條葉蚤或其他十字花科害蟲的相關效果展示，這些資材大都是本所資材研發組涉及的研發題材，可藉此次研討會了解各國學著的研究進度，做為未來研發相關資材的參考。另外在非防治資材的部分，有學者使用黑水虻肥料及家禽肥料等來栽培羽衣甘藍等十字花科蔬菜，結果顯示對蔬菜生長有良好的幫助，且較不受害物的侵害。實際上不要過度依賴化學肥料也是 IPM 裡重要的一環，有健全營養的植物其抗性亦較營養不均的植物來得更有抗性，這些研究也多次證明了這一點。

九、在蘇力菌部分，亞蔬 Dr. Srini 發表其團隊的研究，相關結論為發現使用生物殺蟲劑或化學殺蟲劑管理小菜蛾時，黃條葉蚤的危害也較小，推測可能與受取食的十字花科植物產生異硫氰酸酯 (isothiocyanates)有關。或許能期待使用費洛蒙或天敵管理小菜蛾，黃條葉蚤的危害也能減少。其中應用鮎澤蘇力菌及庫斯蘇力菌在田間甘藍菜田施用防治小菜蛾，意外發現在黃條葉蚤的危害上有減少，但相關機制仍未有探討，然亞蔬團隊的研究中，正是使用由本所技轉予福壽公司的庫斯蘇力菌 E-911 菌株產品速力寶；在楊尚唯助理研究員發表的海報中，即是介紹台灣目前正式核可登記的本土蘇力菌菌株庫斯蘇力菌 E-911 及鮎澤蘇力菌 Ab12，其對於防治小菜蛾有顯著效果，與會研究員因此討論熱烈，並有馬來西亞廠商 ANCOM CROP CARE SDN BHD 廠商因此對此菌株十分有興趣，有極高的意願想要引進庫斯蘇力菌 E-911 菌株產品到馬國使用，會後楊助研即表示回國後將會轉知福壽公司與其接洽。

十、最後一個主題是有關於利用分子生物學技術的進行害蟲防治的研究，並使用了近年的新技術 (CRISPR/Cas9) 進行小菜蛾的防治，其中利用基因編輯及 RNAi 技術讓小菜蛾降低族群的防治技術，雖然在 20 幾年就有相關的概念，但因國內法規及科學倫理問題，於我國難以實現，但仍可作為與會人員的參考，亦可發想如何利用分子生物學的技術，進行深入的研究。而利用分子生物學技術來鑑定相似的寄生蜂的方法也是可做為學習標的之一。

伍、結論及建議

一、本次國際研討會以研發生物農藥及非化學防治方法佔最多篇幅，其次為化學生態學及 IPM 之研究，而分子生物學的研究則最少，可見研究主軸仍以資材開發為主，且以微生物及天然資材為主要研究方向，以應用於小菜蛾的防治。然而，這些資材仍處於功能確立層面，對於商品化及量產部分鮮少有人繼續探討，如果這些有潛力的資材皆能完成商品化並進入市場，應可適量地取代化學農藥的使用，降低化學農藥對環境的衝擊。

二、如同前面所述的 3 個重要主題，與本次派赴參加研討會的人員專長相同，足以顯示本所研發方向與國際一致，此類研討會是重要的國際研究人員交流場合，未來如有與研究相關之研討會，仍建議盡量派員參與，俾以與國際接軌。本次本所人員發表的 2 種非化學農藥防治資材成果 (費洛蒙與蘇力菌)，讓與會的研究人員相當感興趣，也都不約而同地詢問此 2 種資材是否可輸出到國外販賣。由於此 2 種資材皆已技轉給國內業者，但不限於國內販賣，本所與會人員會將相關資訊帶回給技轉廠商，讓業者評估輸出國外的可行性。從各國研究人員的反應可看出，我國目前在生物農藥的發展上應相對屬於較前端的國家，相對成熟的產品較多，且成果也都不錯，期待這些產品未來皆有輸出的可能性並為這些國家帶來農作物害物管理上實質的幫助，也讓我國的研發成果可以到國際上發揚光大。

三、本次會議主辦單位亞蔬有開放講者以視訊方式發表論文，大致上視訊效果良好，然有部分研究人員在視訊過程中有延遲或斷訊的狀況發生。中國學者蕭先生在 Q & A 過程中直接斷訊且不再能連線，以致於無法詳細討論，實屬可惜。全世界在經過 covid-19 的肆虐後，各項網路及視訊設備皆已深入生活當中，就算是柬埔寨被認為是低度開發國家的一員，其視訊過程中仍沒有太大的阻礙，據此，未來倘我國單位欲辦理國際研討會時，視訊發表將會是選項之一，也服務那些不便出國的學者能一起交流相關研究，促進研究視野的拓展，也可以考慮多多推廣至低度開發國家，不會因為先進國家的研究人員無法親自前來而錯失其他國家學習的機會。從這次發表論文可以發現，歐美等西方國家之研究較為深入，探討相關機制或做趨勢預測等，但仍偏向研究性質；而東、中、南亞及非洲地區的研究較為應用研究，尤其是研發新產品為

主。可能是因為歐美國家在推行的時間 IPM 較久，相關資材較為完備，研究人員探討這些相關機制或趨勢預測可做為未來方向做準備；而其他地區因為資材尚未普及，仍依賴化學農藥，故較為著重在資材研發方面。

四、參加本次研討會，可看到各國的研究情形，尤其小菜蛾或蚜蟲天敵的研究，除了棲所的保育，也研究如何讓天敵學習認知，以快速精準尋找到寄主，提高寄生率；另外，印度研究人員也提出有關殼聚糖 (甲殼素) 的萃取方法及在害蟲防治上的應用，文獻及國內研究多以預防病害為主，後續將再進一步瞭解，也和與會報告之研究人員 Dr. Shanthi M.互留聯絡資訊。除了瞭解目前國際上針對小菜蛾與十字花科害蟲的管理研究方向外，相關的研究主題也可作為本所與會人員未來研究主題的發想，由於研究學者來自各個國家，因為不同的風俗民情，或是當地的地區發展情形，研究的內容有基礎的研究到應用的研究，但大家的目的皆來自於解決小菜蛾或是十字花科害蟲的問題，因此研討會十分的聚焦主題，可在短短的幾天內，便瞭解小菜蛾在國際上的危害嚴重性，而因為參與會議的人員也有其他廠商與各國研究單位，也可以因此認識更多學者，並開拓眼界。

五、主辦單位 Dr. Srini 宣布下次研討會預計 4 年後在非洲舉辦，可能與 ICIPE 合辦，建議如果仍有機會，屆時仍可派員參加研討會，與會人員可吸取相關研究新知，各國民俗風情及因地制宜之病蟲害管理方式，或者推廣我國研發的各種優良產品，並執行國民外交，提升我國國際觀感，更讓國際知道本所的研發成果，也讓本所與會人員走向國際化，在一點一滴的累積下，為提升我國國際定位，盡一份小小的心力；另外，ICIPE 為以昆蟲生理生態為研究的研究機構，也是值得參訪的機構。未來將與亞蔬保持聯繫，期能儘早取得研討會資訊，利於爭取經費前往研討會及參訪。

陸、附錄

附錄一：活動照片

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5 月 2 日報到註冊</td>
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112 年 5 月 2 日參與學者大合照</td>
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5 月 2 日 Dr. Srini 開啓序幕</td>
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5 月 2 日陳富翔發表海報論文</td>
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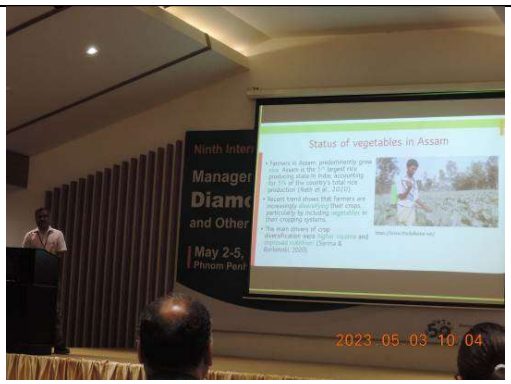
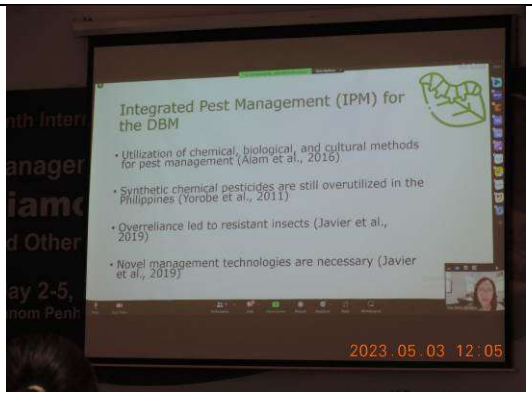


5 月 3 日 Dr. Ravishankar 發表論文

5 月 3 日黃莉欣發表海報論文

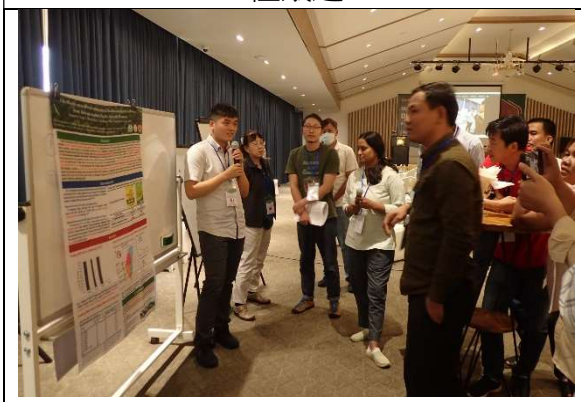


5 月 3 日 Dr. Bautista 視訊發表論文

5 月 4 日 Dr. Shanthi 發表論文

與會人員與柬埔寨學者交流小菜蛾抗藥性議題

5 月 4 日 Dr. Gurr 視訊發表論文



5 月 4 日楊尚唯發表海報論文

5 月 5 日翁崧夏先生發表論文

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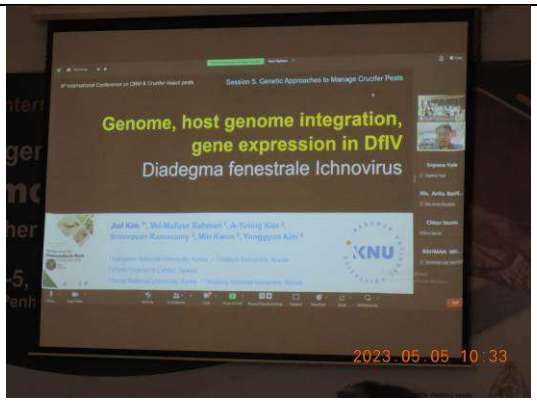
<td> 

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5 月 5 日 Dr. Srini 閉幕結論並宣布下屆會議地點</td>
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會後本次出國人員合影</td>
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附錄二：「第 9 屆小菜蛾和其他十字花科害蟲管理國際研討會」封面、目錄及本所 3 篇發表之摘要(研討會摘要全集另以附件檔案提供)

Ninth International Conference on

Management of the Diamondback Moth and Other Crucifer Insect Pests

May 2-5, 2023
Phnom Penh, Cambodia

Sowing seeds, meeting needs
World Vegetable Center
1973-2023

Schedule

Tuesday, 2 May 2023	
Venue: Himawari Hotel Conference area	
08:30-09:30	Registration
09:30-10:00	Coffee Break (Coffee Lounge)
10:00-12:00	**Inaugural session**
10:00-10:20	Welcome address and Introduction to the Conference (Dr. Srinivasan Ramasamy, World Vegetable Center)
10:20-10:35	Inaugural address by Dr. Marco Wopereis, Director General, World Vegetable Center
10:35-10:50	Inaugural address by Dr. Yann-rong Lin, Deputy Director General – Partnerships, World Vegetable Center
10:50-11:05	Special address by Dr. Bunthan Ngo, Rector, Royal University of Agriculture, Cambodia
11:05-11:20	Special address by Dr. Ker Monthivuth, Director, Department of Plant Protection, Sanitary and Phytosanitary, General Directorate of Agriculture, Cambodia
11:20-11:25	Group Photo

Session 1	**Insect Plant Interactions, Host Plant Resistance and Chemical Ecology of Crucifer Pests and Their Natural Enemies**
11:30-12:00	**The Effect of Herbivory on Diamondback Moth Host-Plant Selection: Implications for Trap Cropping** .....1 Tannner, E.R. and Furlong, M. J.
12:00-13:00	Lunch
13:00-13:30	**Ecosystem services within the vegetable integrated push-pull (VIPPT) protects Brassicas against diamond back moth with improved yield and quality.** .....2 Chidawanyika, F.; Pittchar, J.; Subramanian, S.; Khan, Z. R.
13:30-14:00	**Diamondback Moth (*Plutella xylostella*) and Aphids (*Brevicoryne brassicae* and *Lipaphis pseudobrassicae*) Control in Cabbage Production Using Vegetable Push-Pull Technology** .....3 Boni, S. B. et al.

Wednesday, 3 May 2023

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09:00-09:30	**Promoting Integrated Pest Management for Climate-Resilient Market-Led Cruciferous Vegetable Production in Assam, India** ..... 14 Ravishankar, M. et al.
09:30-10:00	**Scaling of IPM Technologies for Off-Season Production of Leafy Brassicas in Cambodia** ..... 16 Sotelo-Cardona, P. et al.
10:00-10:30	Coffee break / Poster
	Poster session **Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of Pesticide Use in Chinese Cabbage Production in Taiwan** ..... 18 Huang, L. H. et al.
10:30-11:00	**Agronomic Performance of Kales (*Brassica oleracea*) and Swiss Chard (*Beta vulgaris*) Grown on Soil Amended with Black Soldier Fly Frass Fertilizer Under Wonder Multistorey Gardening System** ..... 19 Abiya, A. A. and Niassy, S.
11:00-11:30	**Management of Diamondback Moth in Florida and Georgia, USA** ..... 20 Furuya, A. M. et al.
11:30-12:00	**How do *Bacillus thuringiensis* Biopesticides Reduce Flea Beetle Damage on Leafy Brassicas?** ..... 21 Adhikari, P. et al.
12:00-13:00	Lunch
Session 3	**Insecticide Resistance and Management in Crucifer Pests: The on-going Challenge**
13:00-13:30	**Bacterial Survey in the Gut of Philippine Population of The Diamondback Moth, *Plutella xylostella* L.** 23

Thursday, 4 May 2023

Session 4	Biological and Non-Chemical Methods of Management of Crucifer Pests (Including Organic Agriculture)
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09:30-10:00	**Promoting natural enemy activity in brassica crops: multi-scalar effects** .....34 Gurr, G.M. et al.
10:00-10:30	**Impacts of Increasing Global Temperatures on *Diadegma semiclausum*, an Important Parasitoid of the Diamondback Moth**.....35 Wang, L.Y. et al.
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11:00-11:30	**Potential of Entomopathogenic Nematodes and Biopesticides against Flea Beetles (*Phyllotreta striolata* and *P. chotanica*) on Choy Sum in Hot, Wet and Dry Seasons in Thailand** .....36 Yule, S. et al.
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17:00-17:30	**Impact of Cultural Seasons, Biological and Chemical fertilizers on Major Pests of Cabbage (*Brassica oleracea* L.), their Natural Enemies and Yields in Dschang, West Region of Cameroon** .....48 Sidoine Djomaha, E. and Pakaha Youmbi, C. A.

Friday, 5 May 2023

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Session 3	**Insecticide Resistance and Management in Crucifer Pests: The on-going Challenge**
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Departure of participants

The Study and Development of Mass Trapping System for Sex Pheromone of *Plutella xylostella* (Lepidoptera: Plutellidae) in Taiwan

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ABSTRACT

Diamondback moth (DBM), *Plutella xylostella*, is an important pest of Brassicaceae in Taiwan. The insecticide resistance of DBM is a serious issue. The aim of this study is to develop a mass trapping system for the sex pheromone of DBM. We used synthetic sex pheromone of DBM to develop the best formulation of sex pheromone lure, and the optimal number for mass trapping is 120 traps/ha in this study. There was a lower density of DBMs and a lower infested rate of DBMs on the cauliflowers. Thereafter, we designed various dry traps for DBM sex pheromone. The "2-layer lepidopteran flies up plastic trap" with ventilation holes in the lower layer is as effective as a wing sticky trap in the higher density of DBMs. We hope this system can be introduced into IPM programs for controlling DBMs. The components and mixture ratio of synthetic sex pheromone for DBM in Taiwan have been authorized by technology to a pesticide manufacturer for commercialization and sale.

Keywords

diamondback moth (DBM), *Plutella xylostella*, sex pheromone lure, dry trap

The study and development mass trapping system of sex pheromone for *Plutella xylostella* (Lepidoptera: Plutellidae) in Taiwan

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ABSTRACT

Diamondback moth (DBM), *Plutella xylostella*, is an important pest of Brassicaceae in Taiwan. The insecticide resistance of DBM is a serious issue. The aim of this study is to develop a mass trapping system for the sex pheromone of DBM. We used synthetic sex pheromone of DBM to develop the best formulation of sex pheromone lure, and the optimal number for mass trapping is 120 traps/ha in this study. There was a lower density of DBMs and a lower infested rate of DBMs on the cauliflowers. Thereafter, we designed various dry traps for DBM sex pheromone. The "2-layer lepidopteran flies up plastic trap with ventilation holes in the lower layer" (a.k.a. the No. 3-lep-2-up trap) is as effective as a wing sticky trap in the higher density of DBMs. We hope this system can be introduced into IPM programs for controlling DBMs. The components and mixture ratio of synthetic sex pheromone for DBM in Taiwan have been authorized by technology to a pesticide manufacturer for commercialization and sale.

INTRODUCTION

Diamondback moth (DBM), *Plutella xylostella*, is an important pest of Brassicaceae. Their hosts, like cabbage, Chinese cabbage, broccoli, cauliflower, and radish, are major crops in Taiwan. The ingredients of sex pheromone of DBM were identified as (Z)-11-hexadecenal, (Z)-11-hexadecenyl acetate, (Z)-11-hexadecenol, and (Z)-9-tetradecenyl acetate, many formulation were reported, we should find the most suitable formula ratio in Taiwan. Sex pheromones usually were used to monitor or mass trapping with the sticky paper to catch insects, but the durability of sticky paper is low and it was discarded at the field by user, we have to develop a reusable trap for progress. This poster is reviewing the development process of sex pheromone lure and trap for DBMs, and the research of its application in the field in Taiwan.

The development of sex pheromone lure for DBM

We compared the number of insects attracted to two formulations of DBM sex pheromone lure and a Japanese commercial lure, formulation A attracted the least number of DBMs (24.4±0.6%), and the number of DBMs attracted by formulation B (36.6±5.9%) was not significantly different from that of Japanese commercial lure (35.6±6.6%).

Afterwards, we tested which dispenser is better. The result shows rubber septa (75.2±7.5%) was better than the PVC microtube (22.5±6.4%). After adjusting the material and formula, we finally got the best product (fig. 1). We tested the effective distance of the lure near the cauliflower field, and the results showed that the traps located at the edge of the field caught the most DBMs (54.9±34.1), significantly more than the traps located at 5 m (3.5±2.2), 10 m (2.3±1.8) and 15 m (4.4±2.9) from the edge of the field.

Fig 1. The sex pheromone lure for DBM.

The effect of different sex pheromone trap abundances on the population density of DBM

Previous studies suggested that the attractive distance of DBM lure is 4 m. According to these data, the abundance of traps needed to cover the whole field is about 120 traps/ha. We set different sex pheromone trap (with wing sticky traps, fig. 2) abundances for mass trapping the DBMs in cauliflower fields. The population monitoring result shows that the population in all treatment fields was significantly lower than control fields. The monitoring trend lines of the 120 trap/ha treatment field are more separated from the control field (fig. 3).

Fig. 2. A wing sticky trap.

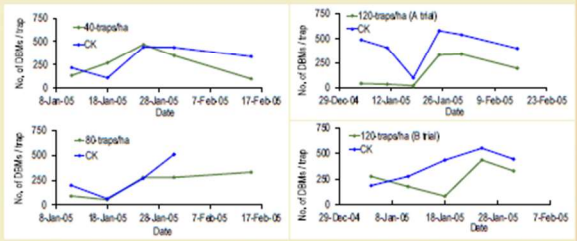

Fig. 3. The influence of the number of traps per hectare on the DBM population density in cauliflower fields in Taiwan, in 2004-2005.

The efficacy evaluation of mass trapping with DBM sex pheromone trap

We set DBM sex pheromone traps (with wing sticky traps) on 3 cauliflower fields with chemical control in place, the abundance of traps was 120 traps/ha, the distance between traps was 8 m. The result showed that all of the mass trapping fields had less infested rate of cauliflowers than the control fields (only applied pesticides), but statistical analysis showed only a significant difference in the third field. So, we summed up the infested rate of all fields. Whether it is the infested rate of flowers or leaves, the mass trapping fields were significantly lower than the control fields (fig. 4).

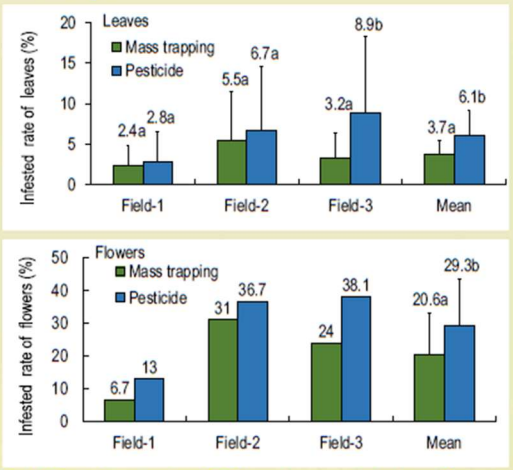

Fig. 4. Effects of mass trapping of DBM sex pheromone lure in the cauliflower fields in Taiwan, in 2007.

The evaluation of different types of traps for DBM sex pheromone lures

We test many different types of traps for DBM sex pheromone lures, including commercial traps and hand-made traps. After comparing various traps, the results of the last trial are shown in Table 1. When the density of DBMs is lower than 200 insects/trap, the wing sticky trap caught most DBMs. But the density of DBMs is higher than 200 insects/trap, all types of traps are equally effective at capturing DBMs. Finally, we chose the F trap (fig. 5) as the commercialization trap. The F trap is a reusable plastic product designed according to lepidopteran taxis, we call it as No. 3-lep-2-up trap, it is a 2-layer lepidopteran flies up plastic trap, and there is ventilation holes in the lower layer.

Table 1. Percentages of trapping number of insect of different types of trap in different population densities of DBM in the field

Types of trap	% of total insect caught	
	Lower density of DBMs	Higher density of DBMs
A	11.0 ± 9.9 c	11.6 ± 5.5 a
B	11.1 ± 9.4 c	14.0 ± 7.1 a
C	17.3 ± 10.4 b	12.3 ± 6.5 a
D	13.7 ± 8.5 bc	12.4 ± 6.0 a
E	11.8 ± 6.5 bc	16.7 ± 5.8 a
F [(1)]	9.9 ± 7.4 c	18.1 ± 7.9 a
W [(2)] (CK)	25.1 ± 19.2 a	14.9 ± 6.4 a

[(1)] 2-layer lepidopteran flies up plastic trap with ventilation holes in the lower layer (a.k.a. No. 3-lep-2-up trap).

[(2)] W: wing sticky traps.

Fig. 5. Commercialized F trap.

CONCLUSION

Sex pheromone lure for mass trapping is an IPM strategy for farmer. The sex pheromone lures for DBM has a little control effect and must be registered as a pesticide in Taiwan. According to the efficacy trial before registration, the abundance of 120 traps/ha in the cabbage field can reduce the application of chemical pesticides by 2-4 times, and the total cultivated cost was reduced by 50,000 NTD/ha. **Sinon corporation** technology transferred this lure and completed the pesticide registration in 2018. Pheromones are a plant protect product that can reduce the use of chemicals. We will improve and promote products to increase farmers' willingness to use them.

Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of pesticide use in Chinese Cabbage Production in Taiwan

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ABSTRACT

In conventional agriculture involving Chinese cabbage production in Taiwan, insecticides are inevitably used to control various insect pests, especially *Plutella xylostella* (diamondback moth, DBM), *Pieris rapae* (imported cabbageworm), and *Phyllotreta striolata* (stripped flea beetle). To reduce pesticide use, we introduced an integrated pest management program (IPM) to Chinese cabbage growers, including the sex pheromone of DBM for monitoring and mass trapping, insecticide Cartap GR and diatomaceous earth for controlling stripped flea beetle larvae in soil, and Bacillus thuringiensis to control Lepidoptera larvae. We designed scouting record sheets for different insect pests to teach growers how to record situations of pest occurrence so that they could launch different control strategies according to the amount of insect population. Furthermore, the environmental impact quotient (EIQ) was used to evaluate the potential impact of pesticides on human health and environment as a decision support tool in IPM decisions. Field use of EIQ can improve the selection and use of pesticides in IPM decisions to reduce the risk of hazards and can also be a useful indicator for impact assessment of IPM programs.

Keywords

Integrated pest management, Environmental Impact Quotient (EIQ), Chinese cabbage

Use of Environmental Impact Quotient in Integrated Pest Management Program Dissemination to Reduce the Hazard Risk of pesticide use in Chinese Cabbage Production in Taiwan

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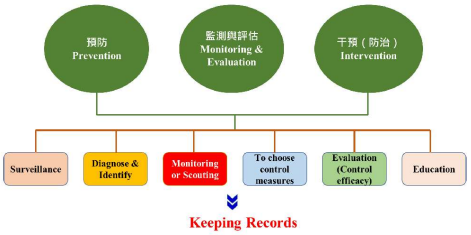
Introduction

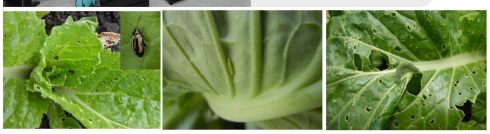
To reduce pesticide use, we introduced an integrated pest management program (IPM) to Chinese cabbage growers, including the sex pheromone of DBM for monitoring and mass trapping, insecticide Cartap GR and diatomaceous earth for controlling stripped flea beetle larvae in soil, and *Bacillus thuringiensis* to control *Lepidoptera* larvae. We designed scouting record sheets for different insect pests to teach growers how to record situations of pest occurrence so that they could launch different control strategies according to the amount of insect population. Plant protection products were applied in pest management, which has certain risks to the environment. The Environmental Impact Quotient (EIQ) is a tool that is being used to measure achievements in pesticide risk reduction. The EIQ was developed in 1992 by Kovach et al. at Cornell University, USA. The EIQ can be a useful indicator when assessing the impact of IPM programs on pesticide risk reduction. The Guidance Document No. 2 of the IPM impact assessment series of FAO in 2008 revealed that The EIQ has been applied to several IPM projects in Asia, such as Vietnam. The purposes of this article are to share how to disseminate the IPM concept and operation principles, and introduce the EIQ to IPM programs for reduction of risk of plant protection products use to the environment.



What is IPM and its frameworks and implementation steps?
The core jobs in IPM are **monitoring** and **keeping record**.

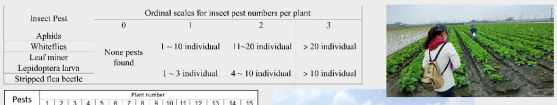
Dissemination of IPM

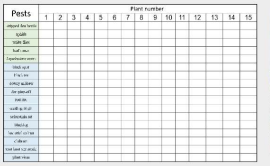
Visit farmers for understanding pest management problems in Chinese cabbage field, such as the most concerning and difficult control pests.



DBM, stripped flea beetle, and cabbageworm are the most difficult control pests on Chinese cabbage in Taiwan.

Insect Pest	Ordinal scales for insect pest numbers per plant			
	0	1	2	3
Aphids	None pests found	1 ~ 10 individual	11~20 individual	> 20 individual
Whiteflies				
Leaf miner				
Lepidoptera larva		1 ~ 3 individual	4 ~ 10 individual	> 10 individual
Stripped flea beetle				





We designed the scouting methods and recording sheets for the concerning pests.

To scout insects and record on the sheets for good decision making and choosing proper and rational control measures.

Prevention

- eliminating eggs, larvae of insect pest and plant pathogens.
- setting pheromone traps for mass trapping and monitoring of *Plutella xylostella*
- giving action thresholds and suggestions, according to level of damage loss by Chinese cabbage farmers

Growth stage of Chinese cabbage	Recommendations for action thresholds	Suggestions of control measures
0 to 10 days after planting	There are at least 10 plants with 2 DBM or 3 cabbageworm larvae, or more than 3 Lepidoptera larvae.	Using Bt
	There are at least 10 plants with 3 DBM or 4 cabbageworm larvae, or more than 4 Lepidoptera larvae.	Using chemical pesticides
	There are at least 10 plants within 3 stripped flea beetle adults.	Using chemical pesticides
11 to 20 days after planting	There are at least 10 plants with 2 DBM or 3 cabbageworm larvae, or more than 3 Lepidoptera larvae.	Using Bt
	There are at least 10 plants with 4 DBM or 5 cabbageworm larvae, or more than 6 Lepidoptera larvae.	Using chemical pesticides
	There are at least 10 plants within 3 stripped flea beetle adults.	Using chemical pesticides
21 days after planting to before harvesting	There are at least 10 plants with 3 DBM or 3 cabbageworm larvae, or more than 3 Lepidoptera larvae.	Choosing Bt or chemical pesticides of shorter PHI
	There are at least 10 plants within 4 stripped flea beetle adults.	Choosing chemical pesticides of shorter PHI

We suggested that the sample size for each field is at least 30 to 50 plants by visual inspection.

Pest control strategies

- ‡ Choosing registered insecticides to control insect pests.
- ‡ Rotation insecticides using different mode of action.
- ‡ Records of spray operations included date, time of day, and environmental condition.

Ecofriendly materials applying diatomaceous earth (DE) for suppression larvae of stripped flea beetle on the seedling stage.

Using insecticide Cartap GR to control larvae of stripped flea beetle before planting.

What is EIQ and how to derive the values ?

The Environmental Impact Quotient (EIQ) is an indicator that evaluates the environmental impact of plant protection products, including their impacts on farmworkers, consumers, and ecosystems. The EIQ value is a figure calculated for a specific active ingredient, according to a formula that includes 11 parameters such as toxicity (dermal, chronic, bird, bee, fish, and beneficial arthropod), soil half-life, systemicity, leaching potential, and plant surface half-life. Each of those parameters is given a score of 1, 3, or 5 to reflect the potential for harm.

DT = Dermal toxicity
C = Chronic toxicity
SY = systemicity
F = fish toxicity
L = leaching potential
R = surface loss potential

D = bird toxicity
S = soil half-life
Z = bee toxicity
B = beneficial arthropod toxicity
P = plant surface half-life

EIQ =
(C)(DT*5)+(DT*P)|
+[(C*(S+P)/2)*SY)+(L)]
+[(D*3)+(D*((S+P)/2)*3)+(Z*P*3)+(B*P*5)]| / 3

Variables	Symbol	Score 1	Score 2	Score 3
Long-term health effects	C	Little-none	Possible	Definite
Dermal toxicity (rbt LD50)	DT	>2000 mg/kg	200-2000 mg/kg	0-200 mg/kg
Bird toxicity (8-day LC50)	D	>1000 ppm	100-1000 ppm	1-100 ppm
Bee toxicity	Z	Non-toxic	Moderately toxic	Highly toxic
Beneficial arthropod toxicity	B	Low impact	Moderate	Severe impact
Fish toxicity (96 hr LC50)	F	>10 ppm	1-10 ppm	<1 ppm
Plant surface half-life	P	1-2 weeks, persistent, herbic.	2-4 weeks, persistent, herbic.	>4 weeks
Soil residue half-life (T1/2)	S	<30 days	30-350 days	>360 days
Mode of action	SY	Non-systemic, or herbicides	Systemic	
Leaching potential	L	Small	Medium	Large
Surface runoff potential	R	Small	Medium	Large

Field use of EIQ = EIQ value × % active ingredient × Dose × number of Applications

We constructed a EIQ estimated platform for calculation Field Use EIQ

The risks to the environment of using pesticides are related to the amount of exposure. The EIQ is a hazard indicator. It has to account for the exposure amount causing hazard risk, which needs additional calculations to obtain an indication of the pesticide risk. A simple equation called the Field Use EIQ was established, which is the summation of the EIQ value multiplied by the percent active ingredient and dosage rate per hectare of each pesticide used in an IPM program.

The use of pesticides and the EIQ field use rating of the first production season of a Chinese cabbage farm in Zhutang Township, Changhua County, Taiwan in 2022.

Pesticide	Dosage form	EIQ	Active ingredient	Dosage (g or mL / ha)	Application	Field EIQ	Field EIQ ranking
Bacillus subtilis(V1326	WP	10.26	$1*10^9$ cfu/g up	251.3	1	2.5901	5
esfenvalerate	SC	31.19	14.5%	294.5	9	3.7972	4
emamectin benzoate	EC	28.28	2.15%	236	9	0.3719	12
chlorfenapyr	SC	37.5	10%	35.9	1	0.461	10
acetamiprid	SC	28.23	20%	143.2	2	2.2985	7
dinotefuran	SC	22.26	20%	557.7	14	6.9225	2
oxamyl	G	33.33	10%	4397.7	9	40.8267	1
lambda-cyhalothrin	EC	49.33	2.8%	118.8	1	0.3957	11
gamma-cyhalothrin	CS	44.05	1.5%	107.7	1	0.1662	13
indoxacarb(a)	SC	37.99	22%	89.7	1	1.0088	8
spirotetramat	SC	35.29	10%	164	3	1.6233	9
BTK ABTS-351	WG	13.33	54% (≥8,000 IU/MG)	197.4	4	2.9578	3
BTA 703-200	WG	13.33	54%	143.6	3	2.8764	6
total	-	-	-	6673.8	58	69.4793	-

The results showed that there are 14 times of application for dinotefuran more than 9 applications of oxamyl. However, the EIQ field use rating of dinotefuran is 6.9 less than 40.8 for oxamyl, because the EIQ value of oxamyl is higher than that of dinotefuran. The EIQ field use ratings for emamectin benzoate and indoxacarb are lower than that of oxamyl, although they were the same at 9 applications. The reason is that the usage and the EIQ value of both insecticides are lower than that of oxamyl.

Conclusions

The EIQ is helpful in providing information about the potential environmental effects of IPM practices. If the EIQ value and percentage of active ingredient in a plant protection product are higher, the usage of that product should be reduced to mitigate the hazard risk to the environment. Therefore, the EIQ field use rating can improve the selection and use of pesticides in IPM decisions, thereby reducing the risk of hazards.

The Effectiveness of Two Subspecies of *Bacillus thuringiensis* Collected from Taiwan against *Plutella xylostella* (Linnaeus)

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ABSTRACT
Bacillus thuringiensis (BT) is a well-known bio-insecticide that has been used for over 50 years to control caterpillars on cruciferous vegetables worldwide, including *Plutella xylostella* (Linnaeus) (diamondback moth, DBM), and noctuid moths. BT is a spore-forming bacterium naturally found in soil and on plant leaves, providing a good choice for eco-friendly agriculture. Two local *B. thuringiensis* subspecies were collected by the Taiwan Agriculture Chemical and Toxic Substance Research Institute (TACTRI) from barns and *Semecarpus longifolius* Blume leaves in Taiwan. One is *B. thuringiensis* subsp. *kurstaki* E-911 from a barn in Taiwan, and the other is *B. thuringiensis* subsp. *aizawai* Ab12 from a plant leaf. Both subspecies were separately transferred through technology to Fwusow Industry of Taiwan in 2005 and 2014 for commercialization and sale. The strains E-911 and Ab12 have been registered in Taiwan in 2011 and 2023, respectively. The commercialized products of *B. thuringiensis* subsp. *kurstaki* strain E-911 and *B. thuringiensis* subsp. *aizawai* strain Ab12 are 60% wettable powder. We used E-911 and Ab12 with artificial diet to feed second-instar DBM. After 72 hours, the mortality of DBM was 96.7% for strain E-911 at 30 ppm and for strain Ab12 at 60 ppm. In the field trial result, 60% wettable powder formulation of strain E-911 and strain Ab12 was recommended to be sprayed twice and three times on fields with DBM infestations. And then, the treatment group with the E-911 and Ab12 powder diluted 1000 times had a 65.6-89.9% and 53.4-58.7% control rate. In Taiwan, most strains of BT come from abroad. The commercial products of E-911 and Ab12 are both new localized BT products in Taiwan. It also provides Taiwanese farmers with more options for effectively controlling the diamondback moth.

Keywords
diamondback moth (DBM), *Plutella xylostella*, *Bacillus thuringiensis*, E-911, Ab12, Taiwan

The effectiveness of two subspecies of *Bacillus thuringiensis* collected from Taiwan against *Plutella xylostella* (Linnaeus)

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Abstract

Bacillus thuringiensis (BT) is a well-known bio-insecticide that has been worldwide used for over 50 years to control caterpillars on cruciferous vegetables, including *Plutella xylostella* (Linnaeus) (diamondback moth, DBM), and noctuid moths. BT is a spore-forming bacterium naturally found in soil and on plant leaves, providing a good choice for eco-friendly agriculture. Two *B. thuringiensis* subspecies were collected by Taiwan Agriculture Chemical and Toxic Substance Research Institute (TACTRI) in Taiwan. One is ***B. thuringiensis* subsp. *kurstaki* E-911** from a barn, and the other is ***B. thuringiensis* subsp. *aizawai* Ab12** from *Semecarpus longifolius* Blume leaves. Both subspecies were technology transferred to Fwusow Industry at 2005 and 2014 for commercialization and sale, and also have been registered in Taiwan at 2011 and 2023. Moreover, the formulation of E-911 and Ab12 commercialized products are 60% wettable powder. The artificial diet 3rd instar DBM were fed with E-911 and Ab12. The results showed that mortality of DBM was 96.7% for E-911 at 30 ppm and for Ab12 at 60 ppm after 72 hours. In field experiments, 60% wettable powder formulation of E-911 and Ab12 were sprayed twice and three times on fields after DBM infestation. And then, the control rate of diluted 1000 times in E-911 and Ab-12 had a 65.6-89.9% and 53.4-58.7%. In Taiwan, most strains of BT were imported from abroad, and annual amount was about 50 million NTD. Therefore, it is important to develop localized BT strain to control pests. The commercial products (E-911 and Ab-12) in this study are both new localized BT products in Taiwan, which can also provide Taiwanese farmers with more eco-friendly options for effectively controlling DBM.

Introduction

BT is a well-known bio-insecticide that has been used for more than 50 years from late 1950s to control agriculture pests. Among BT, the subspecies *kurstaki* and *aizawai* are world-famous to control caterpillars on cruciferous vegetables, including DBM and noctuid moths. (2)(3)(5)

Where were BT strain E-911 and Ab12 collected from?

B. thuringiensis subsp. *kurstaki* E-911 and *B. thuringiensis* subsp. *aizawai* Ab12 were collected by TACTRI from barns and *Semecarpus longifolius* Blume leaves in Taiwan. (1)(4)

What products are make from BT strain E-911 and Ab12 in Taiwan ?

The formulation of E-911 and Ab12 commercialized products are 60% wettable powder. Both subspecies were technology transferred from TACTRI to Fwusow Industry at 2005 and 2014 for commercialization and sale, and also have been registered in Taiwan at 2011 and 2023, respectively. The commercial name of E-911 is Su-li-bao (速力寶) and Ab12 is Nian-ze-bao (黏澤寶) in Taiwan (Table 1).

Table1. The Commercial information of BT strain E-911 and Ab12

Product labeled in Taiwan		
Strain name:	**E-911**	**Ab12**
Commercial name:	**FWUSOW BT1**	**FWUSOW BT-Ab12**
Chinese commercial name:	**速力寶 (Su-li-bao)**	**黏澤寶 (Nian-ze-bao)**

Results

Feeding DBM with Leaf Dipping in E-911

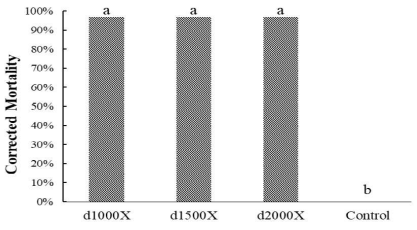

Fig1. Feeding 30 DBM 3rd instar larvae, after dipping broccoli leaves in different dilution folds of E-911 solution for 10 seconds. The corrected mortality of DBM was 96.7% across all treatments after 48 hours.

Feeding DBM with Artificial Diets of E-911 and Ab12

Table2.Insecticidal activity of *Bacillus thuringiensis* products against *Plutella xylostella* larvae with artificial diet to feed DBM (a)

samples	No. of larvae Tested (n)	Cumulative mortality (%) 48h	72h
E-911 30ppm	30	63.3	96.7 ←
E-911 15ppm	30	13.3	36.7
E-911 30ppm	90	66.7	92.2
E-911 15ppm	90	15.6	46.7
Ab12 60ppm	30	43.3	96.7 ←
Ab12 30ppm	30	33.3	70.0
Ab12 60ppm	90	50.0	93.3
Ab12 30ppm	90	43.3	70.0
BTA standard(b) 20ppm	100	71.0	99.0
Water	100	0	0

(a) The *Bacillus thuringiensis* products means products of BT strain E-911 and BT strain Ab12.Third instar Diamondback Moth (DBM) larvae were tested. There were 10 larvae/replicate and 3 and 9 replicates/treatment, 10 replicates/control and standard. A homogeneous BT biopesticide solution was added to all of the artificial diets used in the treatments.
(b) The *B. thuringiensis* subsp. *aizawai* standard (Lot No.:57733V901, potency = 60805 DBMU/mg) in TACTRI.

Using E-911 and Ab12 to control DBM in field experiment

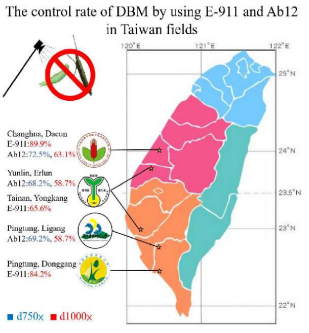

Fig2. All field experiment of E-911 in 2009-2010, and Ab12 in 2017-2018 were conducted in Changhua, Yunlin, Tainan, and Pingtung.

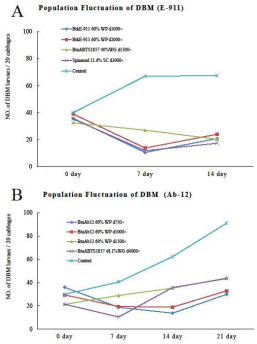

Fig3. The population fluctuation of DBM larvae in field experiment by using E-911 (A) and Ab12 (B).

Conclusion

The commercial products of E-911 and Ab12 are new localized BT products in Taiwan, and the results showed that they both had a good control to DBM whether in lab or field experiment. The study were provided farmers with new eco-friendly options for controlling agriculture pests. In the future, it may also have the opportunity to become a new choice for the use of BT products in the world.

Acknowledgment

1.Some of the results of E-911 in this study were revalidated under a project in collaboration with the World Vegetable Center.
2.The strain E-911 and Ab12 used in this research were collected from study of Dr. Ching-Chou Tzeng (retired from TACTRI) in Taiwan.

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