傳播番茄斑萎凋病毒屬病毒之薊馬及其防治研究

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摘 要

薊馬傳播的番茄斑萎凋病毒屬 (*Tospovirus*) 病毒，廣泛分布世界各地，寄主多達千種以上，包括多種重要蔬菜、瓜果、花卉等作物，經常造成農作物重大經濟損失。薊馬是唯一傳播番茄斑萎凋病毒屬病毒的媒介昆蟲，迄今，全球已確認有 14 種薊馬傳播至少 20 種以上番茄斑萎凋病毒屬病毒。其中 6 種薊馬已有分布台灣之紀錄，包括台灣花薊馬 (*Frankliniella intonsa* (Trybom))、尖角薊馬 (*Frankliniella cephalica* (Crawford))、梳缺花薊馬 (*Frankliniella schultzei* (Trybom))、小黃薊馬 (*Scirtothrips dorsalis* Hood)、南黃薊馬 (*Thrips palmi* Karny) 及蔥薊馬 (*Thrips tabaci* Lindeman)，確認傳播番茄斑萎凋病毒 (*Tomato spotted wilt virus* (TSWV))、花生黃化扇斑病毒 (*Peanut chlorotic fan-spot virus* (PCFV))、番椒黃化病毒 (*Capsicum chlorosis virus* (CaCV))、彩色海芋黃化斑點病毒 (*Calla lily chlorotic spot virus* (CCSV))、洋香瓜黃斑病毒 (*Melon yellow spot virus* (MYSV))、西瓜銀斑病毒 (*Watermelon silver mottle virus* (WSMoV))、番茄黃輪病毒 (*Tomato yellow fruit ring virus* (TYFRV))。本文乃綜合相關文獻及研究調查資料，簡介在台灣媒介病毒的薊馬種類，其分布、植物棲所、生態習性及傳播病毒概況，同時也探討評估各種防治措施對傳毒薊馬之防治效益及適用性，做爲研擬防治對策及田間應用之參考

關鍵詞：番茄斑萎凋病毒屬、薊馬、傳播、防治。

前 言

薊馬屬於纓翅目 (Thysanoptera) 昆蟲，體型微小細長，長約 0.5-2 mm。全世界已記錄薊馬約 5000 種，分布於不同氣候區，薊馬大多以植物及眞菌爲食，取食植物時，利用刺吸式口器穿刺細胞吸取組織成份。在眾多的薊馬中，具經濟重要性者約有 100 種，在台灣則約有 20 種薊馬，因取食農園藝作物造成損失 (王及徐, 2007)，如小黃薊馬 (*Scirtothrips dorsalis* Hood) 、南黃薊馬 (*Thrips palmi* Karny)、台灣花薊馬 (*Frankliniella intonsa* (Trybom))、花薊馬 (*T. hawaiiensis* (Morgan))、蔥薊馬 (*T. tabaci* Lindeman)、蘭花薊馬 (*Dichromothrips corbetti* (Priesner)) 等。有些薊馬不但直接危害植物，也媒介傳播植物番茄斑萎凋病毒屬

病毒 (tospoviruses)。

番茄斑萎凋病毒屬 (*tospovirus*) 在植物病毒分屬 Bunyaviridae 科，屬名來自於本屬模式種-番茄斑萎病毒 (*Tomato spotted wilt virus* , TSWV)。本屬病毒分布廣，寄主中有多種爲重要經濟作物，如番茄、甜椒、瓜類及花卉等，本屬病毒感染農作物往往引起重大的經濟損失，單 1 種番茄斑萎凋病毒在美國 10 年就引起約 14 億美金的損失 (Riley *et al*., 2011)。台灣於 2006 及 2007 年，中南部地區栽培的洋香瓜，先後感染由南黃薊馬傳播的甜瓜黃斑病毒(*Melon yellow spot virus*, MYSV))與西瓜銀斑病毒(*Watermelon silver mottle virus*, WSMoV)(鄧等, 2009)，受害面積約 500 公頃，損失達新台幣二億五千萬元。因此，薊馬間接傳播病毒常常較直接取食危害植物來得嚴重。

全球已紀錄傳播番茄斑萎凋病毒 14 種薊馬 (黃及蘇, 2007; Whitfield *et al*., 2005; Pappu *et al*., 2009; Riley *et al*., 2011)，全屬於錐尾亞目，而以花薊馬屬 (*Frankliniella*) 及薊馬屬最爲普遍。在台灣則有 6 種薊馬傳播植物病毒之紀錄，包括台灣花薊馬、梳缺花薊馬 (*F. schultzei* (Trybom))、尖角薊馬 (*F. cephalica* (Crawford))、小黃薊馬、南黃薊馬、蔥薊馬，除梳缺花薊馬及尖角薊馬在台灣主要發生在雜草上，其他 4 種薊馬在台灣發生相當普遍，經常危害各種農作物造成重大損失。

本文整理全球已記錄之番茄斑萎凋病毒屬種類及其媒介薊馬種類、主要寄主及分布如表一，供植物保護相關人員查閱，尤其是對尚未存在台灣的薊馬及病毒有所了解，以便提高警覺，加強防範其傳入台灣，保障我國農業安全。此外，對薊馬傳播番茄斑萎凋病毒的機制、台灣傳播番茄斑萎凋病毒群薊馬種類的分布、植物棲所、生態習性及管理策略亦有所討論，提供傳毒薊馬防治之參考。

番茄斑萎凋病毒屬病毒

番茄斑萎凋病毒屬(*Tospovirus*)為 Bunyaviridae 病毒科之一屬，Bunyaviridae 科中約有 350 種病毒，番茄斑萎凋病毒屬病毒爲唯一寄生於植物者，其它均爲寄生人類或哺乳類動物之病原菌。番茄斑萎凋病毒屬內之種類鑑定，以核鞘蛋白 (nucleocapsid (N) protein amino acid) 基因的特性、媒介薊馬及寄主植物範圍依據，主要以病毒的核鞘蛋白中相同的核酸低於 90% 則認定爲一新種。本屬病毒之型態結構以番茄斑萎凋病毒 (TSWV) 爲例，爲一具有套模的球型病毒，直徑在 80-110 nm 之間，其基因組包含了三條單股基因體 RNA (ssRNA)。

番茄斑萎凋病毒屬長久以來只有番茄斑萎凋病毒 (*Tomato spotted wilt virus* , TSWV) (Brittlebank, 1919) 爲唯一種類，直到 1990 年(Law and Moyer)發現本屬第二個病毒-鳳仙花壞疽斑點病毒 (*Impatiens necrotic spot virus*, INSV) 後，本屬才有不同病毒種陸續在世界各地被發表紀錄，目前已發現 20 種 (表一)，分布在世界各地，其中以亞洲地區發生 15 種居冠(Pappu, 2009)。而本屬中以番茄斑萎凋病毒 (TSWV)、鳳仙花壞疽斑點病毒及鳶尾花黃斑病毒 (*Iris yellow spot virus*, IYSV) 廣佈全球五大洲。本屬病毒寄主非常廣泛，遍及單子葉及雙子葉 90 科植物 1090 種以上 (Parrella *et al*., 2003)，其中包括多種經濟作物、次要作物及眾多

雜草。著名的番茄斑萎凋病毒 (TSWV) 已知可感染超過 900 種植物，鳳仙花壞疽斑點病毒 (INSV) 則至少可感染 300 種植物。

感染番茄斑萎凋病毒屬病毒的植株，會產生局部褐色壞疽及褪綠的黃化輪狀斑點等病徵，這些病變可能出現在病株的葉、莖、花或果實等部位，伴隨著病毒的擴散而擴大，嚴重時造成生長點萎縮、葉片萎凋。其在植物體內爲系統性感染，以感染生長初期的植物造成危害最大，往往阻礙罹病株的生長發育而矮化，嚴重時導致整株萎凋死亡。

薊馬傳播病毒之機制

薊馬傳播蕃茄斑萎凋病毒屬病毒的機制屬於持續增殖型 (persistent propagative manner)，這種傳播方式有別於其他形式的昆蟲，如非持續性傳播型的蚜蟲，病毒不需經過循環複製，於取食過程中即將病毒傳播出去；如粉蝨傳播形式爲持續非增殖型，病毒雖然可以在粉蝨體內循環移動，但並不會增殖，粉蝨體內只要累積足量的病毒，即可傳播病毒。薊馬則藉由不對稱口器穿刺病株及吸取植物組織而獲得病毒，病毒由口腔進入消化道在中腸進行複製增殖後，透過細胞膜的滲透作用，將病毒移轉至唾液腺，再經過取食的作用，病毒伴隨著唾液注入植株體內。

具傳毒能力的薊馬只限成蟲，而且必須自一齡或二齡初期獲毒的幼蟲發育爲成蟲後，方可將病毒傳播至植物上；老熟幼蟲及成蟲雖然取食病株得到病毒，但卻不具傳毒能力。這種特殊的傳毒機制似乎與本屬病毒在薊馬體內增殖與移轉有關，過去有三種假設理論，說明病毒在薊馬體內如何自中腸移至唾液腺 (Whitfield *et al*., 2005)，但以 Moritz 等 (2004) 提出以薊馬個體發育學的論證較具說服力，同時也說明爲何只有在一齡幼蟲獲毒發育爲成蟲才有傳毒能力。Moritz 等解剖不同齡期的西方花薊馬幼蟲與成蟲個體，利用光學及掃描式電子顯微鏡比較這些個體內中腸、唾液腺及腦器官結構與位置，發現不同生長期，這些器官組織位置有所改變。一齡及二齡初期幼蟲的唾腺及中腸及內臟筋肉細胞均位於胸部，器官組織直接相互接觸，病毒可以在這些相鄰的器官組織間移動，由中腸移到唾液腺。但是當薊馬成長後，腦與唾液腺往前移，而中腸則往後移至後胸，造成這些器官產生隔離空間，因此阻礙了病毒在各器官組織間的移動，病毒無法由中腸移至唾腺因而無法接種自植株上，故成蟲期雖取食病株獲得病毒卻不具致病性。薊馬幼蟲取食病株 30 分鐘後即可獲毒，未成熟薊馬獲毒 1 次，病毒即可在體內增殖循環，當成蟲取食植物時將病毒傳至其他植物上，薊馬終身保留病毒至體內，但無法經卵傳播至子代。

傳播病毒之薊馬

目前全球有 20 種番茄斑萎凋病毒屬病毒由 14 種薊馬傳播，均屬纓翅目 (Thysanoptera) 錐尾亞目 (Terebrantia) 薊馬科 (Thripidae) 之種類，其中花薊馬屬 (*Frankliniella*) 8 種，薊馬屬 (*Thrips*) 3 種，跳薊馬屬 (*Scirtothrips*)、*Ceratothripoides* 及 *Dictyothrips* 屬各 1 種 。其中台灣存在 6 種薊馬傳播 7 種病毒 (表二)。

正確診斷鑑定害蟲及病害種類，在植物防疫檢疫是極爲重要的工作，惟有確認有害生物種類，才可降低國外農業重大害物傳入我國的風險，在防疫上也才能掌握疫情及對症下藥，採取正確有效的防治措施，減少農業生產的損失。薊馬體型細小，要正確分類鑑定實爲不易，均需製成玻片標本，鏡檢比對型態特徵後才能正確分類，爲一複雜且專精的學問。本文通訊作者曾出版「台灣薊馬生態與種類」一書 (王, 2002)，書中紀錄錐尾亞目薊馬 47 屬 120 種，對薊馬的型態及分屬特徵、薊馬種的型態特徵及分類檢索表，均有詳盡的描述介紹。2007 年又針對國內重要薊馬 23 種及國外常被檢出，對台灣農作物具威脅性薊馬 7 種，整理其相關分類鑑定相關資料出版成書 (王及徐, 2007)。近年爲因應植物檢疫或防疫上需要迅速判別薊馬種類，發展幼蟲鑑定分類方法 (林等, 2010)。以上書籍與研究文獻均提供豐富的資訊，供研究人員在薊馬分類鑑定上參考應用。本文限於篇幅不再重複相關薊馬鑑定特徵之文字描述。僅分別就台灣傳播病毒的薊馬簡介其分布及植物棲所、及傳播之番茄斑萎凋病毒之情況等，供未來研究及防治之參考。

一、台灣花薊馬 (*Frankliniella intonsa* (Trybom))

分布及植物棲所：台灣花薊馬分布全世界，尤其是歐洲及亞洲，但近年美國及加拿大也有發生的紀錄。本種薊馬棲息各種植物的花部，種類繁多，在台灣普遍發生在各種瓜類、豆類、玉米、蔥、花生、甘藍、百合、玫瑰及梨等薔薇科植物、菊科植物、蘭花及各種雜草 (王及徐, 2007)。不但出現於台灣平地、中高海拔地區也可發現，不但存在花部，偶而也會危害植物幼嫩組織。早年對農作物危害影響不太嚴重。但近年來，台灣耕作栽培習慣改變，農友將夏季無法生產栽培的溫帶蔬果如番茄、甜椒、甘藍等，移至較冷涼或海拔較高的區域栽植如苗栗縣南庄鄉及南投縣埔里、仁愛及信義鄉等地，因此台灣花薊馬危害此類蔬果較往年更爲頻繁。

主要傳播之病毒爲花生環斑病毒 *Groundnut ringspot virus*、鳳仙花壞疽斑點病毒 *impatiens necrotic spot virus*、番茄黃化斑點病毒 *Tomato chlorotic spot virus* (TCSV)、番茄斑萎凋病毒 (TSWV)。除了番茄斑萎凋病毒在台灣發生，其他 3 種病毒不均存在台灣。根據鄭等(2010)針對番椒病毒病害發生之調查，台灣在 2009 年檢測採集自南投縣仁愛鄉的青椒及辣椒樣本中，檢出茄斑萎凋病毒之比率達 86.8%，田間約有 50% 植株感染；2010 年的檢出比率則降至 32%，田間植株感染率低於 5% (鄭等, 2010)。作者等自 2009 至 2010 年起連續兩年，在每年 6-11 月，以黃色黏板誘集調查仁愛鄉青椒園的薊馬發生密度之結果顯示，2009 年每週黏板上誘得薊馬數平均爲 11.8-111.8 隻；2010 年誘得薊馬數平均 0.1-7.0 隻，所誘得薊馬經鑑定，有 85% 以上爲台灣花薊馬；同時，以西方漬染法 (western blotting) 檢測罹病株上台灣花薊馬體內病毒，其中約有 30% 樣品個體中檢出帶 TSWV 病毒，顯示該區域發生之病毒與台灣花薊馬關係密切，值得再深入探討。

二、尖角薊馬 (*Frankliniella cephalica* (Crawford))

分布及植物棲所：台灣、日本、百慕達、加勒比海群島、中美洲、墨西哥及美國。本種薊馬曾在番茄、柑橘、甘藷、紅樹及鬼針草上被發現，在台灣則普遍

存在多種雜草上，不曾危害經濟作物，直至 2010 年台灣才有其分布之紀錄 (Wang *et al*., 2010)。

主要傳播之病毒爲番茄斑萎凋病毒，尖角薊馬雖紀錄傳播番茄斑萎凋病毒，但在台灣少有在經濟作物上採集到，估計其在台灣散播本病毒的機率風險不高。

三、梳缺花薊馬 (*Frankliniella schultzei* (Trybom))

分布及植物棲所：原分布於熱帶或亞熱帶地區，目前更擴及北美及歐洲地區。本種薊馬在歐美之紀錄爲多食性，取食各種蔬菜及觀賞植物，以棉、花生、豌豆爲主，也會取食番茄、辣椒、甘藷等植物。在台灣發生不普遍，雖曾於空心菜、野牽牛、軟枝黃蟬、粉萼鼠尾草、蔥蘭及立鶴花等採得，但存在之密度不高。

主要傳播病毒為鳳仙花壞疽斑點病毒、菊花莖部壞疽病毒 (*Chrysanthemum stem necrosis virus*, CSNV) 、花生輪斑病毒 (*Groundnut ringspot virus*)、花生頂芽壞疽病毒 (*Peanut bud necrosis virus*)、番茄黃化斑點病毒 (*Tomato chlorotic spot virus*)、番茄斑萎凋病毒(*Tomato spotted wilt virus*) 等 6 種病毒，其中只有番茄斑萎凋病毒在台灣有存在之紀錄，其他四種病毒不存在台灣，但本地對梳缺花薊馬相關之研究報導甚少。本種薊馬有深色與淡色兩型，其中深色型者傳播病毒能力強，淡色型薊馬之傳毒能力尚待研究。

四、小黃薊馬 (*Scirtothrips dorsalis* Hood)

分布及植物棲所：分布亞洲、澳洲、美洲等。小黃薊馬寄主相當廣泛，包括芒果、柑橘、葡萄、茶、玫瑰、茉莉、茄子、花生、綠豆、大理花、非洲菊、洋桔梗、蓮等木本及草本植物，寄主達 150 種以上。

傳播之病毒爲花生芽斑病毒 (*Groundnut bud necrosis virus*)、花生黃化扇斑病毒 (*Peanut chlorotic fan-spot virus*)、花生黃斑病毒 (*Peanut yellow spot virus*)。3 種病毒在台灣只有花生黃化扇斑病毒發生之紀錄，其餘病毒不存在。

五、南黃薊馬 (*Thrips palmi* Karny)

分布及植物棲所：主要分布亞洲、大洋洲及美洲等，歐洲目前無南黃薊馬之紀錄。寄主相當廣泛，包括各種瓜類、豆類、茄科、十字花科、薔薇科、芸香科等植物。

傳播之病毒爲番椒黃化病毒 (*Capsicum chlorosis virus*, CaCV)、彩色海芋黃化斑點病毒 (*Calla lily chlorotic spot virus*, CCSV)、洋香瓜黃斑病毒 (*Melon yellow spot virus*, MYSV) 及西瓜銀斑病毒 (*Watermelon silver mottle virus*, WSMoV) ，台灣均有存在之紀錄。

六、蔥薊馬(*Thrips tabaci* Lindeman)

分布及植物棲所：分布全世界，寄主主要爲石蒜科之蔥、洋蔥、蒜、韭菜等。

傳播之病毒爲鳶尾花黃斑病毒 (*Iris yellow spot virus*, IYSV)、番茄斑萎凋病毒 (*Tomato spotted wilt virus*, TSWV)、番茄黃輪病毒 (*Tomato yellow fruit ring virus*, TYFRV)。台灣目前並無鳶尾花黃斑病毒存在之紀錄。

薊馬之生態習性

薊馬的生活史分爲卵、幼蟲、蛹及成蟲四期，雌蟲產卵於植物組織內，孵化後於植物幼嫩組織上爬行取食，大部分薊馬種之幼蟲行動迅速活潑，如花薊馬屬(*Frankliniella*)，少數行動較爲遲緩喜歡靜止棲息於葉片，如腹鉤薊馬(*Rhipiphorothrips cruentatus* Hood)。薊馬幼蟲分一、二齡，兩齡期蟲體形狀相似，但顏色可能不同，二齡蟲較大。老熟二齡幼蟲會跳離植株，落在附近土面，或是直接在葉背、枝條縫隙等較隱蔽處蛻皮化蛹爲前蛹，前蛹不再取食、排泄，且少有活動。前蛹再蛻皮一次爲蛹，蛹發育成熟後再蛻皮後爲成蟲。成蟲又繼續遷移至植物棲所上取食及繁衍後代。

薊馬由卵發育爲成蟲所需時間、成蟲壽命及產卵數，因薊馬種類、溫度、光線等環境條件及寄主植物而有差異。如在 15、20、25 及 30℃ 時、以茄子飼育南黃薊馬，自卵發育爲成蟲所需日數依序分別爲 43.5、22.7、13.5 及 8.9 日，溫度愈高發育速率愈快，雌成蟲壽命依序爲 71.3、63.5、29.7 及 13.4 日，溫度愈高壽命愈短；產卵數依序爲 7.0、18.1、34.5 及 15.6 粒，在 25℃ 產卵最多。由發育日數及產卵數量高低，推估南黃薊馬適合生活的溫度條件約 25℃ 左右，在此溫度下因發育迅速且繁殖量大，該寄主在此環境條件或季節時容易大發生。故了解探討薊馬的生活習性，有助於掌握防治時機及研擬適當有效的防治策略。

除南黃薊馬，尖角薊馬及梳缺花薊馬在台灣因較不具經濟重要性，相關資料闕如，其餘在台灣傳播病毒之薊馬之生態習性相似。台灣花薊馬、小黃薊馬、蔥薊馬等，在不同溫度及寄主之發育所需日數、成蟲壽命及產卵數等，於「台灣薊馬生態與種類」一書有整理列表摘要可資參考 (王及徐, 2002)，不再贅述。

薊馬之防治

薊馬體形細小，喜歡隱匿聚於心芽、嫩葉、花朵處取食，由於肉眼不易察覺，因而錯失防治時機，造成農作物的損害。此外薊馬產卵於葉肉組織內，受到良好的保護，大部分的蛹於樹皮隙縫、土中休眠鮮少取食，也是造成防治困難的原因。本文所討論的台灣花薊馬、小黃薊馬、南黃薊馬及蔥薊馬等，在台灣分布廣，爲害多種經濟作物，過去一、二十年來，常因氣候環境、作物種類及栽培管理技術之改變等因素，導致防治失敗，加上傳播病毒的問題，使薊馬的防治更複雜化。植物一旦感染病毒無法治療恢復健康，因此，在病害管理策略著重保護或降低病毒病害在作物發病的程度，移除或避免感染源的存在，以及減少病毒媒介昆蟲族群。

減少病毒病害首要之務爲栽植健康無毒之種苗，番茄斑萎凋病毒可以藉由已感染的植物種苗傳入栽培地，因此培育種苗時應保持無雜草並與生產區有所隔離，同時按常規防治傳毒薊馬。當作物定植於田間後應注意田間衛生，應儘快拔除已感染病毒的植株，避免薊馬傳播病毒感染鄰近的植株。許多雜草爲病毒的寄主，往往成爲提供媒介薊馬病毒的感染源，因此栽植作物之前應清除雜草，可避免薊馬傳播病毒危害新植株。

所有防治薊馬的手段中，選擇施以適當殺蟲劑可迅速降低薊馬族群數量，減

少傳播病毒，爲目前在台灣防治傳毒薊馬普遍使用的方法。薊馬對化學藥劑的感受性，常因寄主作物及區域不同而有不同，目前登記於植保手冊上防治各種作物薊馬類害蟲的殺蟲劑，種類達 40 種以上 (王及徐, 2002)。有些藥劑因經常使用，薊馬感受性低，施用田間已不具防治薊馬效果，故必須針對地區、作物而篩選適當藥劑，並經常更換輪替，以維持藥效。近年小黃薊馬危害各種經濟作物，根據農試所研究測試殺蟲劑對芒果上小黃薊馬之毒效之報導 (邱等, 2010)，在 30 種供試藥劑中，僅滅大松、芬殺松、加保扶、丁基加保扶、納乃得、滅賜克及賜諾殺等 7 種藥劑具防治芒果小黃薊馬之潛力。有鑒於台灣花薊馬在農作物上危害日益嚴重，農試所研究人員也曾在室內進行殺蟲劑對其毒效測定試驗 (未發表)，經供試藥劑 4.95% 芬普尼水懸劑稀釋 2000 倍、44% 加保扶水懸劑稀釋 800 倍、48.34% 丁基加保扶乳劑稀釋 1000 倍、10% 克凡派水懸劑稀釋 1000 倍、2.5% 賜諾殺水懸劑稀釋 2000 倍及 50% 馬拉松乳劑稀釋 500 倍等稀釋液處理後 24 h，台灣花薊馬之死亡率均達 90% 以上，供未來田間作物防治台灣花薊馬可選擇參考。薊馬個體微小具隱匿性，易躲藏於花苞內、新芽中、葉片背面、葉片絨毛等處，施藥後蟲體往往因未接觸藥液而無法發揮藥效。故以施藥時應均勻散布於植株上，可提高防治效果。

薊馬的天敵種類甚多，包括捕食性天敵如椿象、草蛉、瓢蚋、薊馬及捕植蟎等，其他如寄生蜂、蟲生眞菌等。其中有些天敵已被應用於農作物上進行生物防治。如台灣薊馬天敵中，南方小黑花椿象 (*Orius strigicollis* (Poppius)) 爲最具壓抑薊馬密度之功能，農試所已成功開發其大量繁殖之技術，釋放於田間防治紅豆豆花薊馬、茄園南黃薊馬，均有壓低害蟲密度提高產量的防治效果 (王等, 2002)。小黑花椿象具細長口器及良好的搜尋能力，具捕食隱匿於花朵等薊馬的特性，用於防治危害農作物的薊馬爲最佳的選擇，惟生物防治對壓低害蟲密度的效果，一般較藥劑使用來得緩慢，對於防治傳毒薊馬的策略，需迅速降低薊馬族群避免散播病毒而言，顯然並不適合做爲主要防治方法，若以藥劑防治爲主並搭配生物防治法，或可發揮共同防治效果，但必須先了解藥劑對天敵的毒效，開發選擇性藥劑避免毒殺天敵，爲急需建立的資料，相關研究試驗在台灣能有待研究人員的努力。

物理防治如銀色覆土資材、濾除紫外線塑膠膜及顏色黏板等，均可防除薊馬，在台灣以黃色、藍色黏紙應用較多。除了偵查或監測發生或調查族群密度，亦有大量放置栽培區誘殺害蟲，達到減少害蟲的方法，此法並不適合單獨做爲防治帶毒薊馬用，主要受顏色黏紙誘集而來者均爲成蟲，薊馬幼蟲不被誘引，而薊馬獲毒帶除均在一齡幼期，誘蟲黏紙無法誘殺以降低帶毒薊馬數量，一旦帶毒薊馬長爲成蟲後，傳播散佈病毒的機率大增。此外，目前黏蟲色紙的在台灣的價格遠高於化學藥劑，基於經濟效益的考慮，也是其在應用上受限之原因。

結 論

台灣的氣候環境非常適合薊馬發生繁衍，存在本地傳播番茄斑萎凋病毒屬病毒之薊馬有 6 種，爲全球傳毒薊馬種類 40%。傳播至少 7 種番茄斑萎凋病毒屬

之病害。這些薊馬經常直接取食產卵或間接傳播病毒病害，爲了防治這些薊馬與病毒，增加許多防治成本，且不一定得到相當的防治效果，因此，如何管理傳播病毒的薊馬是非常複雜與棘手問題。未來研究重點除開發薊馬整合性管理技術，結合用運各種防治法提高防治效果，以解決薊馬傳播病毒造成重大農作物損失之問題。此外，目前國際貿易活動頻繁，農產品自國外輸入的數量與種類日漸增加，具隱匿性的薊馬隨著進口之農產品入侵我國的風險也大爲提高。爲避免台灣尚未存在的薊馬及病毒病害侵入台灣，有賴防檢疫及相關植物保護人員，隨時提高警覺，唯有杜絕外來重大害蟲入侵，台灣農業的生產及國際貿易才能得到最大的保護。

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Thrips vectors of tospoviruses and their control

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Abstract

Thrips-transmitted tospoviruses are a major plant viruses that infect over 1,000 plant species and cause severe yield losses to vegetable and ornamental crops worldwide. Thrips are validated as the only vectors that transmit tospoviruses in a persistent propagative manner. Fourteen thrips species were documented to spread more than 20 identified tospoviruses globally. Among them, six thrips vectors were reportedly distributed in Taiwan, including *Frankliniella intonsa* (Trybom), *Frankliniella cephalica* (Crawford), *Frankliniella schultzei* (Trybom), *Scirtothrips dorsalis* Hood, *Thrips palmi* Karny and *Thrips tabaci* Lindeman. Those thrips were reported to carry one or more of the following viruses that could infect numerous plants: *Tomato spotted wilt virus* (TSWV), *Peanut chlorotic fan-spot virus* (PCFV), *Capsicum chlorosis virus* (CaCV), *Calla lily chlorotic spot virus* (CCSV), *Melon yellow spot virus* (MYSV), *Watermelon silver mottle virus* (WSMoV), and *Tomato yellow fruit ring virus* (TYFRV). This paper compiles the information of relevant literatures and survey data to discuss the current status of thrips vectors in Taiwan including their distribution and plant habitats and their vectoring of viruses. In addition, the suitability and efficiency of various control tactics of thrips vectors for the eventual development of control measures will be discussed.

Key words: thrips, *tospovirus*, transmission, control.

表一、全球番茄斑萎凋病毒屬病毒及其媒介薊馬種類

Table 1. Recognized *Tospovirus* species and their documented vectors

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Capsicum chlorosis virus (CaCV)	*Ceratothripoides claratris*, *Thrips palmi*	Peanut, chili pepper, pepper, tomato, *Hoyaaustralis*, calla lily ,Orchid *Pterostylis* , *Phalaenopsis* orchids	Australia, India, Taiwan, Thailand, China	Chen *et al*., 2007; Gibbs *et al*, 2000; Kunkalikar *et al.*, 2007; Krishnareddy *et al.*, 2008; McMichael *et al.*, 2002; Persley *et al.*, 2006; Premachandra *et al.*, 2005; Zheng *et al.*, 2008
Calla lily chlorotic spot virus (CCSV)	*T. palmi*	Calla lily	Asia, Taiwan	Lin *et al.*, 2005.； Lin *et al.*, 2006.
Chrysanthemum stem necrosis virus (CSNV)	*Frankliniella occidentalis* *F. schultzei* *F. gemina*	Chrysanthemum	Brazil, Japan	Matsuura *et al.*, 2007; Mumford *et al.*, 2003; EPPO, 2005; Nagata *et al.* 2007
Groundnut bud necrosis virus (GBNV)	*F. schultzei* *T. palmi* *Scirtothrips dorsalis*	Peanut, potato, soybean, tomato	Asia, China, India, Iran, Nepal, Sri Lanka, Thailand.	Chiemsombat *et al.*, 2008; Reddy *et al.*, 1995; Singh & Srivatava 1995; Vijaya Lakshmi 1994; Wongkaew 1995

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Groundnut ringspot virus (GRSV)	*F. occidentalis* *F. schultzei* *F. intonsa*	Tomoto, peanut, soybean	Argentina, Brazil, Egypt, South Africa	de Avila *et al.*, 1993; de Borbon & Gracia, 1996; de Borbon *et al.*, 2006; de Breuil *et al.*, 2007, 2008; El-Wahab *et al.*, 2008; Pietersen & Morris, 2002
Impatiens necrotic spot virus (INSV)	*F. occidentalis* *F. schultzei* *F. intonsa*	Begonia, chrysanthemum, cyclamen, freesia, gerbera, impatiens, lisianthus, lobelia, primula, ranunculus	Caribbean Canada, Europe, New Zealand, Mexico, USA	Lebas *et al.*, 2004; Ward *et al.*, 2008; Daniel *et al.*, 1996; Daughtrey *et al.*, 1997; EPPO, 2004; Gent *et al.*, 2006; Gracia *et al.*, 1999; Hall *et al.*, 1993; Hoepting *et al.*, 2008; Jones 2005; Koike *et al.*, 2008; Law & Moyer, 1990; Lebas *et al.*, 2004; Lebas & Ochoa-Corona 2007; Moyer *et al.*, 2003; Paliwal, 1974; Peters *et al.*, 1996; Maluf *et al.*, 1991; Sherwood *et al.*, 2000

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Iris yellow spot virus (IYSV)	*T. tabaci*	Onion, ornamentals, Orchid *Pterostylis*, *Pterostylis* plants	America, Australian, Brazil, Canada, Chile, France, Germany, Guatemala, Israel, India, South Africa, Mexico, Netherlands, New Zealand, Peru, Serbia, Spain	Bulaji'c *et al.*, 2008; Cordoba-Selles *et al.*, 2005; Coutts *et al.*, 2004; Coutts *et al.*, 2003; Daniel *et al.*, 1996; Daughtrey *et al.*, 1997; du Toit et al., 2007; Gent *et al.*, 2006; Gibbs *et al.*, 2000; Hall *et al.*, 1993; Huchette *et al.*, 2008; Kannan & Mohamed 2001; Kritzman *et al.*, 2001; Law & Moyer, 1990; Lebas *et al.*, 2004; Leinhos *et al.*, 2007; Moyer *et al.*, 2003; Mumford *et al.*, 2003; Mullis *et al.*, 2006; Nischwitz *et al.* 2007; Paliwal, 1974; Poole *et al.*, 2007; Ravi *et al.*, 2006; Robene-Soustrade *et al.*, 2005; Rosales *et al.*, 2005; Sherwood *et al.*, 2000; Ward *et al.*, 2008
Melon severe mosaic virus (MSMV)		Melons	Japan ,Mexico	Ciuffo *et al.*, 2008; Shigeharu *et al.*, 2009
Melon yellow spot virus (MYSV)	*T. palmi*	Balsam pear, Melons	China, Japan, Prefecture, Shizuoka, Taiwan	Kato *et al.*, 1999; Chen *et al.*, 2007; Chen *et al.*, 2008; Takeuchi *et al.*, 2009

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Peanut chlorotic fan-spot virus (PCFV)	*S. dorsalis*	Peanut	Taiwan	Chen & Chiu, 1996
Polygonum ringspot virus (PoRSV)	*S. dorsalis*	Wheat	Italy	Ciuffo *et al.*, 2008
Physalis severe mottle virus (PSMV)		Physalis	Asia, Thailand	Cortez *et al*., 2001
Peanut yellow spot virus (PYSV)	*S. dorsalis*	Peanut	China, India	Chen *et al.*, 2007; Gopal *et al.* 2010; Reddy, 1989
Tomato chlorotic spot virus (TCSV)	*F. intonsa* *F. occidentalis* *F. schultzei*	Tomato	Iran, South America	Massumi *et al.*, 2009

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Tomato spotted wilt virus (TSWV)	*F. occidentalis* *F. cephalica* *F. bispinosa* *F. fusca* *F. intonsa* *F. schultzei* *T. setosus* *T. tabaci*	Aster, cabbage, calendula, chrysanthemum, cucurbits, lettuce, pepper, potato, peanut, pineapple, tobacco, tomato, soybean	Algeria, Australian, Canada, Chile, Europe, Iran, Israel, Japan, Kenya, Egypt, Korea, Libya, Madagascar, Mauritius, Mexico, Morocco, New Zealand, Niger, Nigeria, Portugal, Senegal, South Africa, Sudan, Taiwan, Tanzania, Tunisia, Uganda, USA, Zaire, Zimbabwe, Spain	Abad *et al.*, 2005; Anfoka *et al.*, 2006; Ben Moussa *et al.*, 2000, 2005; Brittlebank, 1919; Burgmans *et al.*, 1986; Carter, 1961; Chamberlain, 1954; Cho *et al.*, 1989; Culbreath *et al.*, 1991;Daniel *et al.*, 1996; Daughtrey *et al.*, 1997; EPPO, 2004; Gera *et al.*, 2000; Gracia *et al.*, 1999; Gent *et al.*, 2006; Golnaraghi *et al.*, 2001; Haliwell & Philley, 1974; Hall *et al.*, 1993; Hoepting *et al.*, 2008; Holguin-Pe˜na & Rueda-Puente 2007; Jones, 2005; Kucharek *et al.*, 2000; Law & Moyer, 1990; Lebas & Ochoa-Corona, 2007; Maluf *et al.*, 1991;Massumi *et al.*, 2007, 2009; McPherson *et al.*, 1999; Mumford *et al.*, 1996; Moyer *et al.*, 2003; Ohnishi *et al.*, 2006; Pearson et al, 2006; Paliwal, 1974; Persley et al., 2006; Peters et al., 1996; Rosales et al., 2007; Rybicki and Pietersen, 1999; Sherwood et al., 2000; Sivprasad and Gubba, 2008; Smith, 1932; Smith, 1957; Tate et al., 1991; Todd et al., 1996; Thompson and van Zijl, 1996; Uys et al., 1996; Wangai et al., 2001

Tospoviruses	Thrips vectors	Main host plants	Distribution	References
Tomato yellow fruit ring virus (TYFRV)	*T. tabaci*	Potato, tomato, soybean, ornamentals	Asia, Taiwan, Iran	Golnaraghi *et al.*, 2008; Hassani-Mehraban, *et al.* 2007; Hassani-Mehraban *et al.*, 2005; Rasoulpour & Izadpanah, 2007; Winter *et al*., 2006; Zheng, *et al.* 2008
Tomato zonate spot virus (TZSV)	*T. palmi*	Chili pepper, tomato	Asia, China	Dong, 2008
Watermelon bud necrosis virus (WBNV)	*T. palmi*	Watermelon	India, Indonesia, Japan, Philippines, Thailand	Cannon *et al.*, 2007; Jain *et al.*, 2007; Mandal *et al.*, 2003; Singh & Krishnareddy, 1996
Watermelon silver mottle virus (WSMoV)	*T. palmi*	Watermelon	Indonesia, Japan, Taiwan	Kameya-Iwaki *et al*., 1988; Jain *et al*, 1998
Zucchini lethal chlorosis virus (ZLCV)	*F. zucchini*	Cucumber	Brazil, USA	Tatsuya Nagata, *et al.* 2007

表二、台灣傳播番茄斑萎凋屬病毒之薊馬種類及其傳播之病毒

Thrips vectors	Tospoviruses[z]
Frankliniella intonsa	*Groundnut ringspot virus* (GRSV)*
	Impatiens necrotic spot virus (INSV)*
	Tomato chlorotic spot virus (TCSV)*
	Tomato spotted wilt virus (TSWV)
Frankliniella schultzei	*Chrysanthemum stem necrosis virus* (CSNV)*
	Groundnut bud necrosis virus (GBNV)*
	Groundnut ringspot virus (GRSV)*
	Impatiens necrotic spot virus (INSV)*
	Tomato chlorotic spot virus (TCSV)*
	Tomato spotted wilt virus (TSWV)
Frankliniella cephalica	*Tomato spotted wilt virus* (TSWV)
Scirtothrips dorsalis	*Groundnut bud necrosis virus* (GBNV)*
	Peanut chlorotic fan-spot virus (PCFV)
	*Polygonum ringspot virus (*PoRSV)*
Thrips palmi	*Capsicum chlorosis virus* (CaCV)
	Calla lily chlorotic spot virus (CCSV)
	Melon yellow spot virus (MYSV)
	Watermelon silver mottle virus (WSMoV)
Thrips tabaci	*Iris yellow spot virus* (IYSV)*
	Tomato spotted wilt virus (TSWV)
	Tomato yellow fruit ring virus (TYFRV)

z：*表台灣無該病毒存在之紀錄