土壤病原生態與防治研討會專刊

華民國七十九年十一月十五、十六日於臺灣省農業試驗所國際會議廳



臺灣省農業試驗所
中華植物保護學會　主辦
中華民國植物病理學會

臺灣省政府農林廳　補助

臺灣省農業試驗所
中華植物保護學會　編印

中華民國八十年六月

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土壤病原生態及防治研討會　79.11.16攝於農試所

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台灣省政府農林廳徐副廳長茂樟致詞

各位女士、各位先生：

今天，中華植物保護學會及中華民國植物病理學會爲配合台灣省農業試驗所九十五週年所慶紀念活動，特舉行土壤病原生態及防治研討會，本人謹代表農林廳孫廳長參加此盛會，甚感榮幸。

台灣地區地狹人稠，土地面積爲三百五十萬餘公頃，耕地面積總共僅約九十四萬公頃。因此可資利用的土地資源相當有限。況且，台灣地區人口已逾兩千萬，並繼續不斷地增加，在土地面積不可能再擴大的情況下，如何加强土地之利用開發與保護，將是今後我們齊心努力以赴的目標。最近幾年，欣見環境生態保育人士爲斯鄉斯土之永續地存在和利用，開始努力於防止土壤的破壞與流失之工作。同時，植物保護人員亦已開始重視土壤微生物生態平衡及化學污染的問題，並開始謀求解決之道。例如對於土壤傳播性病害的防治，儘量避免使用化學藥劑，且已研發出非農藥的防治方法來抑制土壤病原菌所引起的植物病害，再如拮抗微生物的利用、抗病育種和土壤添加物之施用等，其主要的目的即在不破壞環境的情況下達到保障作物之高品質及產量。

土壤是一個複雜而充滿活力的有機體，任何不當的耕作措施都可使其遭受難以彌補的損失，如經年累月，密集地使用土地，過量施用化學肥料和化學藥劑，不但易使土壤流失、肥力降低，土壤污染，土壤病害則更形嚴重。因此，在此一時刻舉辦研討會，個人覺其意義非常重大。尤其，在座有多位是從事生物防治、抗病育種、土壤添加物之利用和非農藥防治來防除作物病害多年之專家學者，相信經諸位相互印證及深入討論，將有助於今後從事土地資源之利用與作物病害之防治。最後敬祝大會成功，各位身體健康萬事如意。謝謝各位！

行政院農業委員會高技正清文致詞

徐副廳長、杜所長、各位學者專家、各位女士、各位先生：

今天很不巧在台北有重要會議，所以余主任委員、古處長及陳科長，他們都不能來參加這個會議。我謹在此代表他們講幾句話。

土壤病害的重要性，我想在座各位都是專家，我也就不必在此多說。土壤傳播性病害它的病原菌種類雖然不是很多，但是它所造成農作物的損失，可以說在所有病原菌群裡面是最大的。相對的，在世界上針對這些病害所投資下去的研究和防治的經費也是在所有植物保護措施上佔最高，最龐大的。主要原因在於土壤病原菌，它所引起的病害，在防治上特別的困難，例如我們如果用一般的農藥去防治它，在農藥還沒有殺死病原菌以前，很可能已經被土壤裡面其他的微生物把它分解掉了，反之如果用比較不容易被分解的農藥去防治它，又會造成土壤與水源的污染。因此對土壤病原病害的防治目前世界各國均已朝向非農藥的防治方法去發展。我國也不例外，尤其政府農政單位這幾年來在非農藥防治法的補助之計畫上，已有很多很好的成果與貢獻。最近，也是上個月我應亞太糧肥中心及日本國家農業研究中心的邀請，去日本參加一個國際性的「植物病害及病毒媒介昆蟲的生物防治研討會」。與會者有很多是世界著名的生物防治專家，本人是代表我國去報告我國在植物病害之生物防治法方面最近幾年的成就。我所報告的一共有六項，其中有四項全部都是針對土壤病害在生物防治和非農藥防治方面的成就。因此我報告完後很多各國的專家都非常佩服，在會後更一直來向我道賀，並有詢問一些將來可能合作的計畫。所以今天我們在召開這個土壤病原生態與防治研討會，我有一句話，就是說我們國內在這面的研究絕對不輸於其他各國，某一些部份我們甚至可以說領先其他國家，這個是我要向各位的努力所做的道賀。

這次的研討會，跟杜所長在籌備的時候，本來是想舉辦一個比較大型的國際性會議，並邀請一些國外在這方面學有專長的學人來共襄盛舉。但是後來因爲考慮到有一些無法配合的因素，所以我們就祇維持在這樣的一個型式。我們希望在兩年或三年後，依國內的一些成就及各位的努力，我想應該可以來舉辦國際性的土壤病原生態研究研討會。今天我謹代表農委會在這裡祝土壤病原生態與防治研討會圓滿成功，謝謝各位。

台灣省政府農林廳植物保護科范科長國洋致詞

主持人、各位師長、各位貴賓、各位工作同仁：

今天承邀參加土壤病原生態及防治研討會，深覺榮幸。有關土壤病原生態之經濟重要性及未來的展望，徐副廳長，以及農委會高技正，已經做過非常精要的剖析及指陳，在此不再重覆。唯一必須强調的是根據近年各項調查資料顯示；台灣的土壤病害已有越來越嚴重的趨勢，假如不早日設法謀求完善的解決之道，對台灣農業生產將是一大威脅。近年來，由於經濟的快速成長，國民消費習慣的改變，對精緻的農產品的期望越來越高，因此化學肥料、農藥、石化能源等資材之大量應用，其結果導致許多土壤生態系的紊亂，又因稻田轉作，缺乏水稻的輪作情況下，連作障害及土壤病害已呈多發的現象。目前，本省較嚴重之土壤病害係由青枯病菌、疫病菌、鐮刀病菌、猝倒病菌、根瘤病菌、以及菌核病菌等所引起的病害。縱觀過去的事實，無可否認的，本省植物病理界可以說是人才薈萃，所發表的研究報告也非常多，但是這些報告多半散佚各處，並未匯集成篇，以供應用，殊爲可惜。至於土壤病害防治方面的研究資料非常有限，多數僅止於學術性的探討，可供農林廳實際運用於田間的資料非常的缺乏。因此，熱切地希望各位專家學者能重新評估土壤病害研究的重要性，希望大家共同努力，來設法解決我們目前所遭遇困難的問題。此外爲研究薪火的傳遞，期望新進的研究人員能善爲利用過去研究的成果，精益求精，亦爲今天召開本研討會的主要因緣之一。根據許多報告指出土壤病害防治非常困難，利用藥劑防治，所費不貲，對生態平衡及環境保育亦有相當影響，利用抗病品種極爲理想，但是新品種之選育所需時間又非常的長，得之不易；利用拮抗菌來防治，目前也僅止於在溫室，苗圃和小部份的果樹而已，大面積則還沒有達到實用的階段。總之，土壤病害防治工作雖有萬種困難，但在各位專家鍥而不捨的努力研究下，一定能有所創新，有所突破。在此特寄于無限的期望和祝福，最後祝大會成功，各位貴賓身體健康。謝謝各位！

中華植物保護學會杜理事長金池致歡迎詞

徐副廳長、高技正、范科長、杜瑞章教授、各位老師、各位植物保護界的先進、各位貴賓、各位女士、各位先生大家早安：

今天中華植物保護學會與中華民國植物病理學會、台灣省農業試驗所共同舉辦「土壤病原生態及防治研討會」，承蒙各位女士、各位先生撥冗前來參加，本人謹代表中華植物保護學會以及台灣省農業試驗所向各位表示萬分歡迎之意。

記得在民國七十三年十一月十五及十六日兩天，也曾經在農業試驗所舉辦過一次的土壤病害研討會。時間非常的巧，我們在整整的六年後的今天又重新再來召開一次土壤病原生態與防治研討會，意義非常重大。上一次的植物病原研討會，我們集合了中、美、日三國的專家共聚一堂策劃土壤病害研究的方向，經過六年來大家的努力，雖然土壤病害仍然是我們植物病理上的重要病害之一，但是對許多重要的病害，我們已經在這六年裡研究出了很好的防治方法。誠如高技正剛剛所提，他到日本報告生物防治方法的時候，把我們利用生物防治的方法來防治土壤病害的結果提出報告，深得國際佳評。我們先看看這幾年來香蕉黃葉病，在香蕉研究所的努力下已得到了抗病品種；本來非常棘手而不容易防治的土壤病害，因爲有孫老師發明的 S-H soil mixture，而得到良好的防治；我們更可以到南部去看看利用拮抗微生物防治紅豆根腐病的實際成效。這些成就使我們忝爲此行的一員，共有榮焉。當然，仍然還有很多很好的成就，這也就是今天和明天我們召開這個研討會的原因。利用這個機會請各位主持人、各位主講人能夠把這六年來所得到的傑出成果提出來共同分享；一方面讓我們了解六年來我們做了些什麼，同時也讓我們來共同策劃未來的幾年我們還要再努力些什麼，這就是我們這次開這個研討會最主要目的。這次的研討會幸賴農林廳經費的補助，尤其要感謝農林廳植物保護科范國洋科長以及所有的植物保護科同仁的愛護跟照顧；農業試驗所植物病理系蔡武雄博士和有關同仁任勞任怨的籌劃，使今天研討會能夠順利舉辦。最後敬祝各位貴賓、各位老師、各位女士、各位先生身體健康、萬事如意，研討會圓滿成功，謝謝大家。

中華民國植物病理學會徐理事長世典致歡迎詞

徐副廳長、杜所長、各位貴賓、各位女士、各位先生：

中華民國植物病理學會、中華植物保護學會以及農業試驗所，聯合舉辦本次的土壤病原生態與防治研討會。承蒙各位貴賓蒞臨參與盛會，我謹代表植物病理學會向各位女士、先生，表達歡迎與感謝之意。

剛剛幾位貴賓已經談過土壤傳播性病害的重要性，我不再重覆。土壤傳播性病害確實是很嚴重而且很難防治的病害問題，有待各位專家加緊研究，以研擬有效的防治對策。多年來由於我們的農業主管機關對這問題很重視，在研究經費上大力支持，使國內各研究單位的研究人員能對各類土壤病原做深入而廣泛的研究，成果豐碩。這次研討會，我們邀請多位專家學者，來主講各種土壤病原的生態與防治，就是希望他們能將研究成果和研究心得貢獻出來。相信經由此研討後必能使我們對土壤傳播性病害有更多的瞭解。我們感謝農林廳補助經費支持研討會，也非常感謝農業試驗所提供設備完善的會場，更要謝謝農試所籌備工作人員的辛勞，使得這次的研討會能夠如期舉行。這次研討會也是爲配合農業試驗所成立九十五週年所舉辦的一個活動，農試所這幾年來的研究工作非常積極，研究的成果也是大家有目共睹的，我藉此機會向杜所長以及農試所的各位同仁，表達我們的敬佩跟恭賀之意。最後敬祝大會成功，各位女士、各位先生身心愉快。謝謝！

土壤病原生態與防治研討會專刊 1~16, 1991

台灣土傳性病害研究之回顧與展望

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摘　要

孫守恭 1991 台灣土傳性病害研究之回顧與展望　植保會刊 33:1~16

自 1960 年迄今卅年來，台灣土傳性病害研究已有良好成果，自鐮胞菌、疫病菌、腐霉菌、立枯絲核菌、白絹病菌、菌核病菌、十字花科蔬菜根腐病菌等方面均有相當研究，也涉及抑病土及生物防治的探討。惟土傳性病害日有增加，尙賴研究人員繼續努力，合衷共濟，致力於更高層學術性及實用性的研究。綜觀上述諸病害中，鐮胞菌偏重於西瓜蔓割病及蘿蔔黃葉病，尙有許多鐮胞萎凋病需積極研究。疫病菌之研究偏重於學術方面，成績譽滿中外，尙須在防治方面加强。腐霉菌剛在起步階段，立枯絲核菌研究歷史較長，生物防治尙須努力。白絹病研究最近有突破，希望繼續前進不宜中斷。菌核病在台灣有短暫季節性，在學術上及防治上仍需努力探討。十字花科蔬菜根瘤病近五年來有豐碩研究成果，冀望於加强推廣，嘉惠農民。生物防治及綜合防治、潛隱性疾病及土壤添加物仍是今後研究重點。

（關鍵字：土傳性病害、生物防治、拮抗菌、土壤添加物）

緒　言

早在 1912 年，澤田兼吉即報告 *Sclerotinia sclerotiorum*[87]，以後數年也陸續報告 *Phytophthora* spp.[88]，但當時僅記載地上部病徵，病害本身之研究不多。一方面因土傳性根部病害不爲人注意，其發生也較少，研究人員也不諳研究方法，一旦有病害發生也避而不著手研究。但隨著農業之發展，耕作制度之改變，工商業急劇擴張，農村勞力缺乏，農業機械化及化學肥料大量使用，有機肥日漸減少，栽培密集無休閒，土傳性病害及逐漸嚴重發生（表一）。由於資料累積及國際交流，至 1970 年代土傳性病害研究開始萌動。有二、三事件爲台灣土傳性病害研究之啓發里程碑：1971 年 2 月，美國加州大學斯奈德教授（Dr. W. C. Snyder）來台訪問，洽談與中興大學合作研究鐮胞菌（*Fusarium* spp.），後經國科會與美國科學基金會補助，合作研究達十年之久。其間斯奈德教授研究助手斯密絲博士也參予研究。彼等不但與中興大學合作，也與台灣其他研究機關及學校相互訪問座談，促進土傳性病害研究興趣，貢獻至大。

1977 年 3 月在國科會補助下，請夏威夷大學柯文雄教授來台，舉辦第一屆土壤傳播性病害研討會，講述土傳性病菌之特性並有試驗室研習。在此期間，屏東地區香蕉黃葉病及各地西瓜蔓割病、木瓜疫病、水稻徒長病均普遍發生，土傳性病害之重要性引起農委會、國科會及農林廳之重視，撥款補助研究，各大學及試驗研究機關土傳性病害之研究蔚然成爲風氣。爲配合土傳性病害之研究，1979 年斯奈德教

表一、近年來台灣流行之土傳性病害
Table 1. Soilborne diseases of plants found in Taiwan in recent years

病原菌（Pathogen）	病　害（Disease）
Fusarium moniliforme	稻苗徒長病，高粱苗枯病，甘庶稍腐病，玉米莖腐病，籃筍根腐病
Fusarium oxysparum f. sp. *apii*	芹菜黃葉病
f. sp. *asparagii*	蘆筍萎凋病
f. sp. *batatas*	甘藷蔓割病
f. sp. *cubense, race* 4	香蕉黃葉病
f. sp. *melonis*	香瓜蔓割病
f. sp. *niveum*	西瓜蔓割病
f. sp. *momordicae*	苦瓜萎凋病
f. sp. *pisi*	豌豆萎凋病
f. sp. *raphani*	蘿蔔黃葉病
Fusarium solani	百香果頸腐病
F. solani f. sp. *pisi*	豌豆根腐病
Phytophthora cactorum	草莓果腐病
P. capsici	甜椒及辣椒疫病
P. cinnamomi	酪梨根腐病，柑橘褐腐病，鳳梨心腐病
P. citricola	柑橘根腐病
P. citrophthora	柑橘褐腐病，草莓果腐病，番荔枝黑腐病
P. colocasiae	芋疫病
P. cryptogea	非洲菊疫病，滿天星萎凋病
P. infestans	馬鈴薯晚疫病（近年來似不嚴重）
P. melonis	胡瓜疫病
P. palmivora	木瓜疫病，柑橘褐腐病，蓮霧、印度棗疫病，蝴蝶蘭黑腐病
P. parasitica (P. nicotianae)	鳳梨心腐病，柑橘褐腐病，茄子疫病，蝴蝶蘭黑腐病，洛神葵疫病，菸草黑腳病，茏花疫病，天堂鳥根腐病，番荔枝黑腐病
P. vignae	豇豆萎凋病（莖腐病）
Plasmodiophora brassicae	十字花科蔬菜根瘤病
Pythium aphanidermatum	胡瓜幼苗猝倒病及根腐病，菸草幼苗舞病，森林幼苗立枯病
P. myriotylum	薑軟腐病，菸草舞病，落花生莢腐病
P. spinosum	胡瓜猝倒病，硫球松幼苗猝倒病，木瓜幼苗猝倒病
Rhizoctonia solani, AG-1—AG-4	水稻紋枯病，馬鈴薯黑痣病，甘藍、抱子甘藍、胡蘿蔔、玉米、纖維作物、綠豆、番茄、豌豆、蘿蔔、高粱、大豆等腰折病
Rosellinia necatrix	枇杷、梨等白紋羽病
Sclerotinina sclecotiorum	蔬菜、向日葵、菸草、一串紅菌核病
Sclerotium rolfsii	番茄、胡蘿蔔、落花生、甜菊、菱角、百合等白絹病

授來台之時，舉辦鐮胞菌研習會，1987年國科會邀請加拿大華裔植物病理專家黃鴻章博士來台研究菌核病並舉辦菌核病研習會。鑒於數年來研究成果豐碩，中華植物保護學會成立卅周年時（1984）舉辦一次國際土傳性病害研討會，邀請Dr. John L. Lockwood（密支根州立大學教授），Dr. R. J. Cook（美國農部專家兼華盛頓州立大學教授），柯文雄博士（夏威夷大學教授），宇井格生博士（日本北海道大學教授）、渡邊恆雄博士（日本農林省林業試驗所）來台參加。1983年，亞太糧肥中心在東京舉辦亞太地區作物土壤傳播性病害研究會，邀集美國、台灣、日本、泰國、菲律賓及韓國各專家參加。

自1970年後，我留學國外青年學子獲有博士學位陸續返國，參加土傳性病害之研究行列，計有謝文瑞（加州大學）、黃新川（夏威夷大學）、杜金池（佛羅里達大學）、林益昇（華盛頓州立大學）、劉顯達（科羅拉多大學）、莊再揚（夏威夷大學）、何婉清（夏威夷大學）、高清文（夏威夷大學）、安寶貞（夏威夷大學）以及最近返國之黃振文（喬治亞大學）。同時間國內高階層領導人熱心支持鼓勵，推動研究之進行。值得一提者爲前國科會生物組王世中博士、農委會邱人璋博士、客座教授歐世璜博士均參加土壤病害小組之討論會，令人難以忘懷。

鐮胞菌引起之病害

鐮胞菌（*Fusarium* spp.）是令植物病理人員棘手之菌類，斯奈德教授來台合作研究，打開鐮胞菌研究之門。從稻苗徒長病開始[61]，隨之亞麻立枯病[9]、西瓜、香瓜及甘藷蔓割病[55,28,47]、香蕉黃葉病[59]、芹菜及蘿蔔黃葉病[46,57]；豌豆萎凋病及根腐病[19,20]、蘆筍根腐病及萎凋病、百香果頸腐腐[113]。

稻苗徒長病

自1972年開始，孫、張、宇、余等[61]參予研究，證明本菌（*Gibberella fujikuroi*）爲異絲生殖（heterothallic），八個子囊胞子一半爲雌性，另一半爲雄性，雌雄菌株配對方形成子囊殼，也可在人工培養基（Sach's medium加稻桿）上形成子囊殼。分生胞子之雌雄比爲1：1，但也有中性胞子。在台灣子囊殼出現時期在六月下旬降雨之時，亦即第一期水稻收獲之前。子囊殼成熟後遇雨即放射胞子，汚染稻種，成爲重要之感染源。*Fusarium moniliforme*（*Gibberella fujikuroi*之分生胞子）在土中存活約120日，由以上之研究，完成稻苗徒長病之病害環。

西瓜蔓割病

雖然過去已有二、三報告，但以土傳性生態研究乃開始於黃氏之學士及碩士論文[55]。西瓜蔓割病菌（*F. oxysporam* f. sp. *niveum*）在土壤水分50～80%時存活最好，紅壤及壤土有利其存活。與玉米或甘蔗輪作，或土壤中添加洋菇廢土、田菁及大豆莖葉均可使土中病菌密度下降。在田間，西瓜蔓割病菌可存活於再生稻、香附、畔茅等野生雜草之老根上。鐮胞菌在培養中易於變異，隨培養日數逐漸增加。變異之方向爲：胞叢型（野生型）→白色菌絲型→粘膜菌絲型→粘膜型，培養150日後，79%呈現變異。變異菌株病原性降低，果膠分解能力降低，存活力弱。在田間，硝態氮可使土中病菌密度降低，銨態氮則使其升高。黃、孫氏[62]發現彰化溪湖一處土爲抑病土，縱加入病原菌（每克土中加入1～5×10^3菌體），西瓜亦不發病，將抑病土加之於導病土中（50%以上），導病土即有抑病現象。將抑病土加熱至100℃ 30分鐘，抑病力即消失。抑病土中腐生鐮胞菌約爲導病土之6～12倍，其他眞菌及細菌亦多，抑病土含磷及有機質較多。

蘿蔔黃葉病

民國70年6月在台中縣新社鄉水井村及南投縣埔里大平頂同時發現蘿蔔黃葉病，經鑑定爲*F. oxysporum* f. sp. *raphani*，爲台灣之新紀錄[57,85]。羅、孫氏報告蘿蔔黃葉病發生於有機質缺少、pH低之粘土中，田間雜草馬齒莧、野莧、細柄黍、鴨舌黃之根部寓有黃葉病菌。壤土不利黃葉病菌之存活，壤土中胞子發芽及病害發生均低，壤土中細菌含量高。黃氏等在水井村作綜合防活示範，以免賴得千倍液或抑病土粉衣蘿蔔種子，田間施用1% S-H添加物並加用甘藍下位葉，結果顯示處理區增產40%，

防治率比對照區高 42～45%[57]。

羅氏自芥菜及芥藍分離得類似蘿蔔黃葉病菌，但前者寄主範圍廣，後者不爲害芥菜，電泳分析二菌之蛋白質帶也有差異，芥菜及芥藍之黃葉病菌可能爲 *F. oxysporam* f. sp. *conglutinans*[85]。

豌豆萎凋病及根腐病

民國 70 年秋冬季台灣中部豌豆發生萎凋病，經 Lin 等[112]證明爲萎凋（*F. oxysporum* f. sp. *pisi*）及根腐病（*F. solani* f. sp. *pisi*），二者均爲台灣新紀錄。兩種病菌田間垂直分佈多在 0～25 cm 之耕犁層，26～30 cm 之壓成盤處無病菌，40 cm 處又有少數。萎凋病菌呈聚集式水平分佈，根腐病菌爲均勻分佈[24]。兩期水稻後病菌密度下降至不可見，但種植豌豆後又陸續增加，旱作豌豆田中病菌消長不大，種子帶菌爲主要感染源[112]，但再生稻、稗、雀稗、節花路蓼、小葉灰藋、龍葵、山芥菜等之根部也寓有少數病菌[19]。汪等[20]報告在台灣 *F. oxysporum* f. sp. *pisi* 有二個生理小種，Race 2 及 Race 5。一如其他鐮胞菌，豌豆萎凋病菌隨培養日數而發生變異：菌叢菌（野生型）→粘膜菌絲型→粘膜型。菌叢型病原性最強，隨變異而降低，菌叢型及粘膜菌絲型在土中存活良好，粘膜型幾乎無法存活[26]。林等報告氰氮化鈣及 S-H 混合物可防治豌豆萎凋病，但後者不能防治根腐病。在水田地 S-H 混合物不但可防治萎凋病，且有增產效果。氰氮化鈣之效力在於其釋放尿素及氰酸，S-H 混合物之效力在於尿素並促進拮抗菌之產生[86]。

甘藷蔓割病（*F. oxysporum* f. sp. *batatas*）

1977 年廖朝暐完成一份相當分量的學士論文[47]。自病株分離得之病原菌有胞叢型及粘膜型，病原性無差異。菌絲生長適溫爲 24～32 ℃，產胞適溫爲 24 ℃。大胞子發芽適溫爲 22 ℃，小胞子發芽適溫爲 28 ℃，厚膜胞子發芽在 32～36 ℃之間。低溫（0 ℃，7 小時）處理或營養分（5% 葡萄糖加 0.05% proline）可促進厚膜胞子發芽。產胞與炭氮比成正比，但至 C/N = 30 時達至高峰。澱粉有利菌絲生長及小胞子產生，麥芽糖於大胞子及厚膜胞子產生。菌絲型及胞叢型之腐生力強，土壤 pH4.5～5 最適於發病，但甘藷蔓切口乾燥六小時後即可阻步病菌之侵入。台農 40 號最抗病，依次爲台農 22、27、42、56。腐生之鐮胞菌可作爲交叉保護之用。

芹菜黃葉病

1979 年鹿港地區芹菜發生黃化現象，經筆者分離得 *Fusaium oxysporum*，曾紫華[46]以芹菜黃葉病之研究完成其碩士論文並證明其爲 *F. oxysporum* f. sp. *apii*（FOA）。FOA 除爲害芹菜外，也侵害芫荽，但不爲害同科之胡蘿蔔。台灣無抗病品系，國外抗病品種西洋芹菜亦感病，但較本地種略抗。幼苗期最易受害，大株稍有抗性。FOA 之生長適溫爲 24～28 ℃，最適 pH 爲 5.2。水潛勢在－10 Bar 時菌絲生長及產胞最好，－1 至－54 Bar 間均可發芽。FOA 產生脂肪、蛋白質、尿素及 PTE 分解酶。野生型菌落呈粉紅色至紫色，胞叢多，隨培養時間增長可變爲白色菌絲型、粘膜菌絲型，最後變爲粘膜型。變異後之菌株病原性大減，但存活力無差異。FOA 亦可寄生於馬齒莧、牛筋草、小葉灰藋、假吐金菊等雜草之根上並可在其上繁殖，故而增加土中之病菌密度。

香瓜蔓割病

香瓜蔓割病可能很早即存在於台灣，但無研究報告。1979 年筆者在中南部發現病株並分離得 *F. oxysporum*，1981 年周立瓠以此作爲碩士論文[28]。證明其爲 *F. oxysporum* f. sp. *melonis*。每克土中含 1.5×10^3 繁殖體於十日內即可使香瓜幼苗發病，農友公司之銀河香瓜爲抗病，天香及雪露爲中抗，餘均爲感病。本菌在水潛勢－2.34 bar 時生長最好，－51.27 bar 時停止生長，產胞亦同。土壤中添加碳氮比較低之蝦殼、雞糞對本菌有抑制作用，碳氮比高之玉米粉、樹薯粉則促進其繁殖。在苗栗崎頂發現抑病土，在抑病土中厚膜胞子發芽率爲 96%，但 24 小時後發芽管均崩解。在導病土中厚膜胞子發芽率爲 89%，發芽管無崩解現象。在抑病土中接種病原菌 20 天後發病率爲 30%，導病土中爲 80%。抑病土中之腐生眞菌較多（32×10^3），細菌亦多（3×10^6），導病土中眞菌爲 8×10^3，細菌爲 1.4×10^6。

亞麻立枯病

1965 年無名氏報告台灣亞麻發生立枯病（萎凋病），其病原菌爲 *F. oxysporum* f. sp. *lini*。杜氏[9]報告 1968 年彰化縣秀水鄉及福興鄉發病百分率爲 10.9%，在 4600 公頃亞麻中有 120 公頃（2%）因立枯病全部廢耕。但亦有田發病率低。經研究顯示該田爲抑病土，萎凋病在抑病土中不因連作而增加，反而減少。病原菌在抑病土中增加緩慢（8%），在導病土中增加 23～66%。加熱處理後抑病力未消失。抑病土爲粘土，酸鹼值爲 6.4～8.0，有機質 3.03～3.84%。

百香果頸腐病

Lin 等首先報告百香果（*Passiflora edulis* Sims）頸腐病係由 *F. solani*（Marti）Sacc 引起[133]，其有性世代爲 *Nectria haematococca* Berh. & Bro.（異名爲 *Hypomyces solani* (Berk. & Bro.) Snyder & Hansen），黃色種百香果有抗病性。自豌豆、菜豆、胡瓜、咖啡、枳殼等植物分離得之 *F. solani* 對百香果無致病力。Lin 等並證明爲害百香果之 *F. solani* 爲同絲生殖（homothallic），因之 Snyder 及 Hansen 認爲同絲生殖之 *F. solani* 爲腐生性[114]，似有修正之必要。

苦瓜萎凋病

1981 年 6 月，黃及孫在彰化溪湖發現苦瓜黃化、萎凋、莖部維管束褐化，經分離培養，得 *F. oxysporum*，接種試驗證明對苦瓜有病原性。再以西瓜、香瓜、絲瓜、胡瓜、甘藷蔓割病菌及芹菜、蘿蔔黃葉病菌作接種試驗，只有苦瓜之 *F. oxysporum* 引起苦瓜萎凋，孫、黃氏訂名本菌爲 *F. oxysporum* f. sp. *momordicae*，爲新紀錄之分化型[115]。目前苦瓜萎凋病已蔓延至全省各地，爲苦瓜之首要病害。

番茄萎凋病

國外普通發生之番茄萎凋病（*F. oxysporum* f. sp. *lycopersici*），台灣迄未發現。僅 1944 年出版之台灣農家便覽中述及本病之病徵，但缺乏正式文獻報告，是否爲鐮胞菌萎凋病，頗有疑問。澤田氏之菌類調查報告中亦無記載。1981 年 11 月黃振文在高雄縣彌陀鄉發現病株，經分離培養及接種，證明其爲 *F. oxysporum* f. sp. *lycopersici*。據農民稱，發病番茄係荷蘭品種 WS-11，係荷蘭種子商委託在台灣採種，自病株及荷蘭進口之種子，均帶有病原菌（0～75%）。

唐昌蒲萎凋病

1963 年蔡雲鵬報告 *F. oxysporum* f. sp. *gladioli* 引起球莖乾腐，田間萎凋病由謝氏[80]首先報告。病株球莖帶菌率較健株多 10 倍，種植後球莖上病菌蔓延至根上再侵入至維管束，引起黃化萎凋。溫水 57.2℃處理球莖 30 分鐘可消除病菌，但發芽率降低。撲克拉（25% prochloraz）125 ppm 浸球莖三小時可清除球莖上病原菌，可供推廣之用。

胡麻萎凋病

胡麻（*Sesamum indicum* L.）萎凋病，1990 年鄭安秀首次發現於台南市台南區農業改良場內胡麻田內（鄭安秀未發表資料），經分離接種證明其病原菌爲 *F. oxysporum* f. sp. *sesami*，目前尚未普遍。

疫病菌引起之病害

台灣地處亞熱帶，高溫多雨，疫病菌很普遍。1945 年前，澤田氏歷經二十餘年調查，計有 35 種[84]。後經張氏[49,50]及 Ho[103]重予校訂，再加最近安及柯[110]的新種三個，台灣的疫病菌計有 21 種：

Phytophthora boehmeriae Saw.
P. cactorum (Leb. & Cohn.) Schroer.
P. capsici Leon.
P. cinnamomi Rands
（=*P. cinchonae* Saw.）
P. citricola Saw.
P. citrophthora (R. & E. Smith) L.
P. colocasiae Rac.
P. cryptogea Peth. & Laff.
P. cyperi (Ideta) Ito
（=*P. cyperi-iriae* Saw.）
（=*P. cyteri-rotumdati* Saw.）
P. melonis Katsura
（=*P. drechsleri* Tucker）
P. heveae Thomp
P. humicola Ko & Ann
P. ingestans (Mont.) de Bary

P. insolita Ann & Ko
P. katsurae Ko & Chang
P. leesiae Saw.
P. macrospora (Sacc.) Ito & Tanaka
P. nicotianae Bred de Haan
(Syn. *P. parasitica* Tuck.)
(=*P. alli* Saw.)
(=*P. formosae* Saw.)
(=*P. lycopersici* Saw.)
(=*P. melongenae* Saw.)
(=*P. murragae* Saw.)
(=*P. ricini* Saw.)
(=*P. taihokuensis* Saw.)
P. palmivora (Butt.) Butt.
(=*P. carica* (Hona) Hori)
P. vignae Purss.

在此21種疫病菌中，因作物栽培之變遷，已有數種少有發現而失去其重要，茲將近年來重要疫病菌簡介如下：

Phytophthora cactorum

澤田（1927）首先報告爲害苧麻[88]，現苧麻已無栽培，以後即無本菌之報告。1978年高、呂氏報告爲害草莓，引起革腐病（果實）[42]。本菌爲同絲生殖，以卵胞子及厚膜胞子越冬，雨水爲游泳胞子形成之必要條件，也是病害傳播之主動力。花苞形成初期，噴射70%免得克寧混合可濕性粉劑（Ronilan-M）500倍，可以防治之。

Phytophthora cinnamomi

澤田（1942）報告爲害雞納樹，當時澤田[84]訂名爲 *P. cinchonae* Saw.，即 *P. cinnamomi* 之異名。近年來，爲害鳳梨引起心腐病[41,49,50]，爲害酪梨引起根腐病[93]，在美國加州是酪梨主要病害。據Ann及Ko[93]之研究，*P. cinnamomi* 普遍存在於台灣各地土壤中，森林區更爲普遍，但並未招致嚴重病害發生，柯氏認爲台灣是本菌原產地之一，長久以來的演化，已與本島植物形成共存之組合。其A^1及A^2均存在於台灣且菌株間變異性存在。如得自柑橘之菌株與自土壤鳳梨、酪梨之菌株有明顯之差異，柑橘菌株可在36℃下生長，亦不產生厚膜胞子，但各菌株之蛋白帶均相同，此種現象符合台灣爲 *P. cinnamomi* 原產地之假說[93]。

***Phytophthora parasitica*（＝*P. nicotianae*）**

澤田氏首先報告爲害茄子，以後又報告爲害番茄及蓖麻，當時命名爲 *P. melongenee*[84]。1955年後，陳大武、李英敏等報告 *P. Parasitica* 爲害鳳梨、柑橘、洛神葵、蝴蝶蘭、康乃馨、番荔枝、百香果等。柑橘裾腐病爲重要病害，*P. parasitica* 爲病原菌之一，另外尚有 *P. citrophthora* 及 *P. palmivora*。陳氏[41]之鳳梨心腐病研究最爲詳盡。本菌以厚膜胞子存活土中，無論耕作地或處女地均本菌之存在，顯示本菌爲本地產而非由外地引入。夏秋颱風或陰雨連綿，造成鳳梨心腐病猖獗。菌系間病原性有差別，寄主範圍也不同，顯示 *P. parasitica* 有分化現象或有不同菌系。波爾多液、大富丹、好速殺、大生A-40均可防治鳳梨心腐病，有機汞最有效，但已禁用。

Phytophthora palmivora

本菌在台灣亦極普遍，引起木瓜疫病[54]、柑橘裾腐病及褐腐病[3]、蓮霧及印度棗疫病[49]。澤田[84]報告爲害無花果及蓖麻（當時命名爲 *P. carica*）。黃氏等[54]之木瓜疫研究最爲詳盡，高溫多雨時木瓜被害嚴重，罹病木瓜果腔內產生大量厚膜胞子，病果落於地下，增加土中病菌密度。接種試驗得知本菌尚可侵害柑橘、洛神葵、荔枝、番茄、鳳梨及馬鈴薯，亦在雜草節節花、亨利馬唐、短穎馬唐、白花霍香薊等之根部寄生。以礦物鹽溶液浸洗菌絲，除去有機養分，可使其產生大量胞囊，其中鈣鹽效果最好。

Phytophthora capsici

1977年呂、高氏[30]及1983年張氏[50]均報告本菌引起甜椒及辣椒疫病，張氏[50]又報告茄子疫病也是本菌引起的。最近（1990）安寶貞又報告本菌引起康乃馨萎凋病[4]。呂、高[30]指出本菌菌絲生長溫度爲12～28～32℃，遊走子發芽溫度爲12～28～40℃，8及12℃游走子形成最多。尚未發現厚膜胞子，亦無卵胞子，在台灣 *P. capsici* 爲A^1配對型[30]。除爲害甜椒及辣椒外，接種試驗亦侵害番茄、茄子、西瓜、洋蔥、苦藤、蘆薈、香石竹及吊鐘花。

Phytophthora citrophthora

1919年澤田氏[84]報告各害柑橘果實，但爲害樹幹引起褐腐病更爲重要（李英敏未發表資料），惜缺乏專題研究。安小姐[3]自全省229個柑橘園中之土壤，罹病果實、根系、葉片分離，也得到 *P. citrophthora* ，而以根系最多，均屬 A^1 配對型，北部地區較多。1979年，高、呂氏[42]發現本菌引起草莓果實之革腐病，1990年黃氏[60]報告本菌引起番荔枝果實黑腐病（另一病原菌爲 *P. parasitica* ）。

***Phytophthora citricola* saw**

1927年澤田[84]自柑橘果實分離而得並命名爲新種。近年來謝（關西柑橘場65年年報）及安[3]均自柑橘園中土壤及根系分到此菌，台灣北部較多。平板培養時不產胞囊，但在水中可形成，胞囊形狀不規則，在PDA培養基上菌落呈菊花型。1983年張氏[50]報告本菌爲害草莓果實，屬同絲型。

Phytophthora colocasiae

1914年澤田[84]首先報告台灣芋疫病，當時命名爲 *Kawakamia colocasiae* (Rac.) Saw.，芋疫病仍普遍發生於台灣全省各地，但缺專題研究，可能是芋不是重要蔬菜之故。Ann等[94]採集全省疫病標本，分離得799個菌株，與 *P. nicotianae* var. *parasitica* 之 A^1 及 A^2 配對型菌株對峙培養，證明台灣之芋疫病菌株均屬 A^2 型，此乃顯示 *P. colocasiae* 並非台灣土產。

Phytophthora eryptogea

1983年張氏[50]報告：黃振文自埔里非洲菊（ *Gerbera hybride* Hort. ）萎凋病株分離到 *Phytophthora* sp.，經張和喜博士鑑定屬 *P. cryptogea* 。安小姐也自梨山福壽山農場菊花萎凋病分劃。本菌生長適溫爲22～25℃，爲害溫帶地區之花卉，台灣高冷地栽培花卉，應特別注意。

Phytophthora melonis

Ho[103]認爲 *P. melonis* 與 *P. drechseri* 爲同種。1977年高及呂[37]首次在台灣報告本菌引起胡瓜疫病。近年來胡瓜疫病至爲猖獗，林及吳[25]對胡瓜疫之生態及防治有深入研究。本菌之胞囊不具脫落性，但可藉灌溉水及雨水將胞囊及游走子飛濺至地上部，引起萎凋。在淹水狀況下，病菌在土中僅能存活四週，故與水稻輪栽，可減少胡瓜疫病。接種源並非來自土壤或種子，而是來自附近之灌溉水。土壤中添S-H混合物，地上部噴射滅達樂，可有效防治之[25]，二者單獨施用則無防治之效。

Phytophthora heverae, P. humicola, P. insolita

此三種疫病菌係由柑橘園土壤中分離而得，對柑橘無病原性。*P. heveae* Thomp 可自檳榔根部分得，國外報告 *P. heveae* 可爲害橡膠樹、可可椰子、檬果、酪梨及番石榴[3]。後二者係由Ko及Ann定名，均爲新種[110]，對柑橘無病原性，惟安[92]報告 *P. imsolita* 爲害多種植物，*P. humicola* 可爲害蘋果果實及胡瓜。

Peronophthora litchii Chen et al

1934年台灣大學陳其昌教授在其家中荔枝園發現六月間荔枝果實腐爛落地，由病果分離得一種藻菌，其形態頗似露菌 Peronosopra ，但又可人工培養，故又似疫病菌 Phytophthora ，經數年研究，1961年發表論文，定名爲—新屬 *Peronophthora litchii* Chen ，稱爲露疫病[101] 1978年Ko等提升爲—新科 Peronophthoraceae[109]，此科中目前只有 *P. litchii* 。5～6月間荔枝成熟之際若多雨，荔枝果實被害嚴重。本菌生長適溫爲27～28℃，8～20℃低溫處理菌落30分鐘，再移之於室溫下20分鐘即可釋放游走子，16℃處理者游走子最多。高及呂[39]報告荔枝露疫病菌胞囊發芽有數種方式：(1)發芽形成發芽管，(2)發芽釋放游走子，(3)發芽管頂端再形成小胞囊。胞囊之形成法頗似疫病菌。安氏[91]報告於濃霧之時本菌爲害花穗引起花腐病。78年度植物保護手冊中推荐5～6月間兩季來臨前或發病初期，撒佈腈醌銅、鋅錳克絕、快得寧或鋅錳乃浦，每週一次，約4～5次即可防治之。

疫病菌之其他研究

近年來安及柯對台灣之疫病菌生態、生殖、卵胞子發芽、酶的產生及一般調查作一系列研究[3,4,5,91-98,110]。卵胞子不易發芽，但經過錳酸鉀處理及照光，即可發芽，二個月培養者發芽率較高。異激素生殖（Hormonal heterothallism）係安、柯氏首創之假說[96]，異質的配對

型 A^1 及 A^2 菌株不需菌體之接合交換遺傳質，只需其分泌之荷爾蒙刺激即可產生卵胞子。氏等發現將 *P. parasitica* 或 *P. cinnamomi* 單胞菌株培養於含有殺菌劑 Chloroneb 或 Ethazol 的培養基中，A^1 配對型可轉變爲 A^2 配對型，反之亦然[103]。*P. paraaitica, P. cinnamomi, P. palmivora. P. capsici* 均產生脂肪分解酶、磷脂分解酶及尿素分解酶，*P. parasitica* 及 *P. palmivora* 亦產生果膠酶、澱粉酶 DNAse, pectate transeliminaase，但菌株間有明顯之差異[98]。

腐霉菌（Pythium）引起的病害

腐霉菌爲最普通常見之土棲多犯性病菌，引起幼苗猝倒病及根腐病。1943年前，澤田[84]報告有四種：*Pythium aphanidermat*（茄子及胡瓜綿腐病）、*P. debaryarum*（甜瓜之枯病）、*P. hydnosporum*（苧麻立枯病）、*P. spinosum*（金魚草及蔥苗腐病）。近年來有較深入研究，只是量的方面尚少。但鑒於目前提倡水耕設施園藝，腐霉菌的問題不可忽視。

***Pythium aphamidermatum*（Edson.）Fitz.**

本菌之寄主範圍很廣，過去報告爲害胡瓜、茄子、菸草[84]，硫球松幼苗、木瓜幼苗。民國72年玉米台農351號推出，莖腐病發生嚴重[15]。杜、蔡等報告以滅達樂（Ridomil-MZ）可有效防治。於玉米幼苗期（播種後35～40日）在1～4節處塗抹每克含卵胞20～30個之病土泥漿一層，接種後置於35℃之人工溫室中（濕度100%）三日後移至室外調查發病率作爲抗病篩選。

1987年林氏等[22,23,88]對胡瓜猝倒病及根腐病作詳盡研究。以胡瓜幼苗或馬鈴薯之塊切片測定土中接種源絕對潛勢，得知土中卵胞子密度與發病呈正相關（$Y = 0.78X + 20.22$，Y＝發病率，X＝馬鈴薯片被纏化率）。ID_{50} 爲每克土中卵胞子爲7至8個[27]，有少數土爲抑病土，其接種源密度爲每克土中須有58個卵胞子。以S-H混合物0.5%加於土中，可抑制病菌之存活，其機制爲尿素之作用，但礦灰有附加效果[24]。

***Pythium debaryanum* Hesse**

松本巍首先報告本菌引起菽草舞病，1962年陳報告杉木幼苗立枯病也本菌所引起尚有其他菌類[40]。陳氏並推荐施用硫酸鋁酸化土壤誘發 *Trichoderma* spp. 大量繁殖，可抑制 Pythium。陳其昌氏[102]報告本菌引起硫球松幼苗猝倒病，除本菌外，尚有 *P. aphanidermatum, P. spinosum* 及 *P. vexans*。

***Pythium myriotylum* Drechsler**

有關本菌之報告不多，僅知它引起薑軟腐病、落花生莢腐病及菽草舞病，其中以薑軟腐病頗爲嚴重[27]。

***Pythium spinosum* Saw. 及 *P. ultimum* Trow.**

前者引起硫球松及菜豆幼苗猝倒病[102]，後者爲害木瓜，引起幼苗猝倒病。林等[88]報告 *P. spinosum* 亦引起胡瓜猝倒病，發病適溫爲24～28℃，*P. aphmidermatim* 亦引起胡瓜猝倒病，發病適溫爲32～36℃。前者發生於冬季，後者發生於夏季。

Rhizoctonia solani Kühn 引起之病害

R. solani 爲多犯性重要病原菌，但1945年以前有關本菌之研究不多，只1919年澤田[84]報告菜豆大粒白絹病及水稻紋枯病，且當時病原菌命名爲 *Hypochnus sasakii* Shirai。自1960年迄今三十年間，有關 *R. solani* 之研究報告計有43篇以上，自蔡、杜之鐘麻及棉花腰折病[8,10,74]，水稻紋枯病[13,45,48,70]，馬鈴薯黑痣病[6]、鳳梨根腐病、柑橘裾腐病、木瓜腰折病、落花生黑莢病[16]以至最近之菊花莖腐病[30]、玉米紋枯病、菱角紋枯病及康乃馨莖腐病[89]。

雖然 *Rhizoctonia solani* Kühn（菌核世代）早於1858年訂名，其擔子世代世於1956年訂爲 *Thanatephorus cucumeris*（Frank）Donk，但有很長時期其學名非常混亂，常被稱爲 *Corticium solani*，*Pellicularia filamentosa* 或 *Hypochnus sasakii*，杜氏曾有整理報告[11,12,14]，頗具參考價值。柯教授[108]指出 *R. solani* 爲原始型病原菌，其生活史可分爲五期：病原期、寄生期、休眠期、腐生期、存活期。杜等以土壤平板法誘使產生擔胞子[10,119]，自鐘麻、黃

麻、棉花分得之 *Pellicularia filamentosa*（*R. solani*），其病原性強弱不同，似有生理分化現象[120]。杜及張[12]以菌絲融合法將各地分離之 *R. solani* 區分爲五個菌絲融合群；AG-1（來自花生、大豆、亞麻、水稻、菜豆、茄子、高粱），AG-2（來自香椒、亞麻、萊菔、莞荽、茄子），AG-4（來自青葱、番椒、菊花、西瓜、黃麻、木槿、亞麻、茄子），AG-5（來自大豆、土壤）。本菌以菌核及菌絲存活於土中之有機物殘體上，自表土至30公分深處均有之，愈深愈少。但若種植感染性作物（黃麻），土壤中接種源密度可增加25～30%。

由 *R. solani* AG-1引起之水稻紋枯病，爲本省之重要病害，每年被害百分率超過10%以上，成爲重要之風土病[12]。菌核爲初次感染源，菌核附著於植株上，分蘗期稻叢間濕度增大，菌核開始發芽感染水稻，而後菌絲交織於稻葉間進行二次感染，故初次感染源多寡爲紋枯病嚴重與否之重要關鍵[12]。管、劉、郭[48,70]報告紋枯病菌分泌果膠分解酶、磷脂分解酶，吳氏報告紋枯病菌亦產生 Phenyl acetic acid 及 meta, para-hydroxyphenye acetic acid。

對稻紋枯病而言，目前尚無抗病品種，仍以化學防治爲主。歷年來篩選藥劑已有15種：福多寧、滅紋乳劑、鐵甲砷酸銨、甲基砷酸鈣、保粒黴素、滅普寧、維拉黴素、賓克隆等（植保手冊1990）。生物防治也選出數種拮抗菌 *Aspergillus* spp., *Penicillium* spp., *Nocardia* sp., *Bacillus, subtilis, Trichoderma harzianum.*[18,30,31,43,44,118]，但田間效果不彰。只劉氏以 *Trichoderma koningii* 之耐免賴得菌株之培養濾液拌紅豆種子或水稻殼及米糠培養之 *T. koningii* 放入植穴中（每穴一克），可以防治紅豆根腐病（*R. solani* AG-4）[71]。

Sclerotium rolfsii Sacc. 引起之白絹病

S. rolfsii 有性世代之學名也一度頗爲混亂，1931年 Curzi 命名爲 *Corticium rolfsii*，1964年 West 命名爲 *Pellicularia rolfsii*，杜（1975）歸之於 Athelia rolfsii[11]。

S. rolfsii 爲亞熱帶之重要土傳性多犯病原菌，菌核之殘存力強，不易防治。1919年澤田即報告菜豆、番茄、胡蘿蔔、菸菜、落花生、黃麻、鐘麻、古柯樹等之白絹病[84]。1970年後，吳龍溪及劉嵋恩以白絹病之研究爲主，楊、吳氏以 PCNB 處理白絹病菌，促進變異，變異菌株可耐250 ppm之 PCNB，仍形成菌核，病原性穩定且殘存力更強[64]。劉及吳證明菌核黑變乃因多酚氧化酶隨菌核之成熟而增加之故，與人之黑髮、馬鈴薯塊莖黑變及花生冠腐病菌（*Aspergillus niger*）胞子變黑相似，而非蟲漆酶及兒茶酚氧化酶之故[68]。劉及郭研究白絹病菌之菌核形成過程並發現於菌絲長滿培養皿後翻面再培養之，可同步形成大量菌核[69]。最近甜菊、菱角及百合花相繼發生白絹病[33,72,81]。杜等以 P.E. 塑膠布覆蓋地面吸收太陽熱能以防治白絹病[17]，覆蓋處理者中午土中溫度可達51℃，兩週內40℃以上之時間可達119小時，足以殺死菌核，若再添加苜蓿、太陽麻或玉米莖，效果更佳。方氏[2]報告尿素及其他氮化物如氰氮化鈣、硝酸銨、氯化銨、硫胺等皆能抑制菌核發芽，尿素及氰氮化鈣更能殺死菌核。土中之微生物如 *Trichoderma harzianum* 及 *Fusarium ventricosum* 能放出尿素酶，分解尿素產生氨氣，殺死菌核，此乃尿素防治白絹病之機制[2]。

Sclerotinia sclerotiorum 等引起之菌核病

菌核病出現於台灣冬、春季低溫多雨之時，台灣中、北部發生多，寄主範圍極廣，澤田1912[84]報告多至29科104種植物，謝、邱整理中外文獻，寄主植物有134種[82]。其間松本氏首次報告菸草菌核病，黃東麟繼之作菸草菌核病防治試驗，以後即未見有關菌核病之研究。1976年始吳文希報告大蒜菌核病[121]，劉惠元研究菌核病菌之生態並得知該菌分泌果膠分解酶、纖維分解酶及磷脂分解酶[66,67]。菌核存活時間很長，1～4月低溫多雨時菌核發芽形成子囊盤，子囊胞子放射感染多種植物。Huang 等報告培養在10～16℃下形成之菌核，不經休眠在21℃濕濾紙上照光，三週間即形成子

囊盤，在25～30℃培養下形成之菌核，需四週方可發芽[104]。蘇[90]及劉[67]自腐爛之菌核上分得數種拮抗菌包括放線菌細菌及眞菌，其中 *Gliodladium delequenscens* 及 *Penicillium vermiculatum* 之拮抗力最强。李、吳[7]也分得 *Trichoderma viride* 及 *Gliocladium virens* ，其防治效果與殺菌劑 DCNA 及免賴得相同。 Wu[123]報告除 *T. viride* 外，利用太陽熱能及氰氨化鈣均可抑制菌核產生子囊盤。

Anton de Bary 1884 訂 *S. sclerotiorum* （ Lib. ）學名，另有異名 *Sclerotinia libertinia* Fuckel 1870，1972年 Karf 及 Dumont 修訂爲 *Whetzelina sclerotiorum* （ Lib. ），但迄今多數人仍用 *S. sclerotiorum* 。

葱小菌核病（ *Ciboria alli* ）

1919年澤田[84]報告蔥及洋蔥小粒菌核病係由 *Sclerotinia alli* Saw. 引起。秦登 1951年報告台北發生嚴重並以阿蘇仁防治之。呂、吳[28]亦報蔥小菌核病在北部發生情形，並介紹修訂之學爲 *Cibronia alli*（ Saw. ） Kohn., 其子囊胞子 4大4小（大小比 1:1 ），小子囊胞子不發芽，夏季以菌核越夏。

桑椹菌核病（ *Ciboria shiraiana*（ Henn. ） Whetzel ）

1919年澤田[84]首先報告，病原菌爲 *Sclerotinia shiraiana* Henn., Whetzel 及 Wolf 鑒於桑椹菌核病菌缺少分生胞子世代，乃修訂其學名爲 *Ciboria shiraiana*（ Henn. ） Whetzel。 1980年桑椹菌核病在南投縣中興新村大發生，Lin 及 Lo[111]報告越冬菌核落於土中，翌春降雨而溫度爲 12～16℃時，菌核發芽形成子囊盤。劉[66]報告除草劑 Atrazine 及 Diuron 、殺菌劑免賴得、 DCNB 及 Ronilan 均可抑制子囊盤之形成。

十字花科蔬菜根瘤病

由 *Plasmodiophora brassicae* Wor. 引起之十字花科蔬菜根瘤病，是古老病害之一。 1933年澤田[84]首次報告在台灣發生，以後即無本病之報告及研究。 1985年頃，根瘤病在新竹桃園地區普遍發生，謝文瑞教授乃開始其本病系列研究。謝等[75]調查全省 119處土壤，有 47處含有根瘤病菌，但只有 9處發生病害，分佈於桃園、新竹及台中。土壤 pH 在 4～7.7 間，感病品種爲芥菜、四川榨菜、不結球白菜、結球白菜及油菜。甘藍、芥藍、花椰菜、青花菜及蘿蔔未見有根瘤形成。謝等[78]亦報告在台灣十字花科蔬菜根瘤病菌之生理分化共有二型：ECD 16/0/0 及 ECD 16/0/31 。蘆竹、香山、大里、大肚、二林等地屬 ECD 16/0/0 型，思源、南山二地屬 ECD 16/0/31 型。甘藍、青花菜及花椰菜屬 ECD 16/0/0 型。

楊及謝在土中添加 0.5% 或 1%S-H 混合物，可有效抑制青江白菜根瘤病之發生，進一步發現僅 S-H 混合物之蚵殼粉加礦灰或單獨使用礦灰也具有防治之效[65]。礦灰中之氧化鈣及氧化鋁可降低青江白菜根毛的感染率，單獨使用碳酸鈣亦可抑制根瘤病，結論謂土中鈣離子是防治根瘤病的主要成分[77]。育苗土中添加 1% 碳酸鈣或礦灰，在育苗袋中培育白菜幼苗 32 天後移植於病土中，根瘤病發生率便爲 13% ，而對照處理爲 50% ，高含量的鈣具有更好的防治效果[52]。此方法簡便而經濟，值得推廣。

抑病土及生物防治

1975年杜等首先發現彰化縣秀水鄉亞麻萎凋病（ *Fusaium oxysporum* f. sp. *lini* ）之抑病土[9]。抑病土中接種亞麻萎凋病菌，種植亞麻亦會萎凋，但不因連作而增加病害，反而減少病害。抑病土中病原菌增加緩慢，約爲 8% ，而導病土病原菌增加約爲 23～66% 。該抑病土爲泥板岩。 1984年黃及孫[55]在彰化縣溪湖發現西瓜蔓割病（ *F. oxysporum* f. sp. *niveum* (FON) ）之抑病土，在抑病土中， FON 厚膜胞子發芽率爲 18% ，在導病土中爲 81～93% 。抑病土中每克土壤接種 FON $2.5\sim6\times10^3$ 菌體，西瓜幼苗發病率爲 20% ，導病土爲 80% 。抑病土及導病土之 pH 分別爲 7.1 及 6.4 ，抑病土屬粘土，有機質含量高，磷之含量高出導病土約六倍。抑病土中腐生之 *Fusarium* spp. 較導病土多 6～12.5 倍，將抑病土加熱（ 100℃，

30分鐘）其抑病力即消失。但若再添加由抑病土或導病土中之微生物，抑病土之抑病力即可恢復，但導病土則仍不抑病[58]。抑病土之抑病效應與土中病原菌之密度有關，當每克土中含菌量爲10^3或5×10^3時，均可抑制病害之發生，當密度增至10^4時，發病率亦僅爲14%，若密度增爲5×10^4時，抑病土之抑病力即消失[55]。Huang等[105]證明抑病土在鹼性液中產生揮發性氣體，有抑制病原菌胞子發芽之能力，以微生物抑制劑如Rose bengal、Streptomycin或Rubigan處理抑病土，可部分或全部消除其抑病力，導病土中添加微生物或豆餅等，仍不能使其成爲抑病土，由此可知抑病土之抑病力爲生物性及非生物性。莊氏[50]在高雄縣亦發現香蕉黃葉病（*F. oxysporum* f. sp. *cubense*, race 4）之抑病土，其特性與黃氏等之抑病土相似。

王及謝[1,76]在花蓮及彰化發現十字花科蔬菜根瘤病之抑病土，抑病土之pH值高，含有高量鈣離子，加熱處理未消滅其抑病力，故爲非生物性。

生物防治爲近年來世界各國植物病理界研究重點，台灣亦很活躍。自單純的利用拮抗眞菌及細菌至間接的利用土壤添加物以增加拮抗菌、腐生菌及微量元素，達致防治病害效果[6,18,30,31,43,44,67,90,118,124]。拮抗菌及腐生微生物普遍存在於一般土壤中，在培養皿內之拮抗效果明顯，但施之於田間往往效果不彰，其原因尙在探討。劉[77]以稻殼米糠培養*Trichoderma Koningii*，每植穴放一克*T. Koningii*菌種，或以*F. Koningii*胞子懸浮液拌種紅豆種子，均可增加健康株數14～56%吳、劉、陳[30,31,118]分離得拮抗菌*Aspergillus* spp.、*penicillium* spp.、*Trichoderma.* spp.及*Bacillus subtilis*等對*R. solani*有强大拮抗效力。可防治菊花莖腐病，尤其以鋸木屑培養*Penicillium* sp.、*T. harzianum*或*Bacillus subtilis*施於土中之防治效果特優[118]。

傳統的土壤添加物爲古老的農業操作，主要爲維持土壤肥力，其對病害之防治效果不易評估。1983年孫及黃[63,116,117]發展成功S-H混合物，是農工業副產物再加尿素、硝酸鉀及過磷酸鈣而成，可防治西瓜蔓割病、蘿蔔黃葉病、豌豆萎凋病、胡瓜猝倒病及根腐病、十字花科蔬菜根瘤病、番茄青枯病，示範試驗顯示可防治薑軟腐病（*Puthium myriotylum*）、荔枝露疫病（*Peronophthora litchii*）及絲瓜萎凋病（*F. oxysporum*），又可防治甘藍緣枯病（缺鈣）、柑橘缺鎂、缺鐵等症，又可使檬果、荔枝、龍眼提早開花結果。

土壤傳播性病害研究之展望

隨農業之開發，積約栽培，化肥施用及至設施園藝，土傳性病害有日漸增加趨勢，而土壤中病原菌之生態環境至爲複雜，吾人所知者不多，雖然近十年來國內外研究漸多，但資料仍嫌欠缺，亟需今後積極研究。

一、生物防治爲根部病害防治之重要策略，其成功可能性高，台灣應繼續積極研究。拮抗菌及腐生菌之利用，爲生物防治之技巧，單純的室內或溫室試驗均有令人興奮結果，如何促進其施用於田間之效果，爲今後努力重點。這方面需集合菌類生理、植物病理及土壤微生物專家共同協手研究。拮抗菌之生理、營養需求、礦物質及土壤質地、溫濕度等關係，吾人瞭解不多。最重要者爲拮抗菌株之篩選，菌類變異爲普遍現象，拮抗菌亦然，如何挑選拮抗力大而生存强之菌株是研究者之智慧。筆者認爲自抑病土中挑選出之拮抗菌及腐生菌具有莫大潛力，而抑病土之特性研究乃爲維持拮抗菌及腐生菌存活及繁殖之本。

二、潛隱性疾病之肆虐：所謂潛隱性病害（subclinical disease）乃指有些菌類寄生於植物根部，不引起明顯病徵，但可導致生長漸衰及產量降低。目前所知者有*Pythium* spp.、*Fusarium* spp.等常寄宿於植物根部，長久以來未被發現，當土壤燻蒸後，作物生長立即旺盛，產量大增，潛隱性疾病之影響得以顯現。迄今潛隱性疾病之研究尙在發軔階段，值得植物病理人士加以注意。也許潛隱性菌類是生物演化過程中生態體系之一環，若遽而除去，是否引起重大病害之入侵，也是未卜之天，不可不注意。

潛隱性疾病在宿根栽培、連續栽種同一種作物或生長期長久之作物或樹木方面較多，除

菌類關係外，營養的缺乏或不平衡尤其微量元素也可能是因子之一。近年來許多次要性疾病或慢性病害逐漸增多，爲植物病害方面值得注意的新課題。

三、土壤添加物之研究：長久以來，農民添加堆肥、廄肥、草木灰或綠肥於田土中，主要目的爲維持土壤肥力。自工商業發達後，農業人口銳減，有機添加物之施用日漸不用，專施化學肥料，久之乃發現土傳性病害日有增加，才領悟到有機添加物之重要性。自從 S-H 混合物發展出並經多年室內及田間試驗證明可防治土傳性病害並促進作物生長。黃氏於 1990 年推出之 SF-21，防治濕地松幼苗猝倒病效果卓越（尚未發表資料）。類似之合成添加物可望有更多出現，以抑制難以化學防治之土傳性病害。近年來有心人士在提倡有機農業，以解救農業企業化之危急，土壤添加物正符合有機農業之理念。

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ABSTRACT

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During the past three decades, studies on soilborne diseases have been carried out extensively including diseases caused by *Fusarium* spp., *Phytophthora* spp., *Pythium* spp., *Rhizoctonia solani, Sclerotium rolfsii, Sclerotinia sclerotiorum* and *Plasmodiophora brassicae.* Research also extended to suppressive soils and biological control. Among the above-mentioned diseases, more detaild studies were concentrated to *Fusarium* wilt of watermelon, Fusarium yellows of radish, ecology of *Phytophthora,* Pythium damping-off of cucumber, diseases casued by *Rhizoctonia solani, Sclerotium rolfsii* and *Sclerotinia sclerotiorum.* Studies on *Plasmodiophora brassicae* and control measures by soil amendment, especially the effect of calicium, received high appraisal.

(Key words: soilborne diseases, biological control, antagonistic microorganisms, soil amendments)

土壤病原生態與防治研討會專刊 17~35, 1991

Etiology, Biology and Control of a Soilborne Root Rot Complex of Green Peas

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ABSTRACT

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The field incidence of pea root rot in southwestern Ontario averaged 26%. The root rot complex has severely curtailed green pea yield. In order to resolve the etiology of this complex, a total of 782 fungal isolations were obtained from 465 samples collected from 33 pea fields. The isolations yielded *Fusarium solani* f. sp. *pisi, F. oxysporum* f. sp. *pisi, Aphanomyces euteiches* and *Pythium* spp. in 7:4:1:1 frequency. The ratio of races 1 and 2 in the *F. oxysporum* isolates was 7:4. *F. solani* did not appear to be highly specialized and no attempt was made to determine its race profile. The disease severity caused by *F. solani* (root rot), *F. oxysporum* (wilt), *Pythium* and *Aphanomyces* averaged 3.2, 8.7, 2.6 and 4.0, respectively, on a 0-9 scale. Plants with Fusarium wilt usually died while those with Fusarium root rot showed various degrees of stunting and yellowing but rarely died. *Pythium* and *Aphanomyces* are considered to be minor problems in Ontario. Based on this information, a disease damage index (DDI) was developed to rank the relative importance of these four root rots. The DDI of a root rot equals the total amount of root rot (26.5%) × the frequency of occurrence of each fungus × the severity of disease caused by each fungus. The DDIs for *F. solani, F. oxysporum, Pythium* spp. and *A. euteiches,* were 45, 71, 5 and 8, respectively. Therefore, Fusarium wilt is the most damaging disease followed by Fusarium root rot. While *Pythium* and *Aphanomyces* root rot are of minor importance. Based on the etiological and biological findings, an integrated control program has been developed. The program includes: (a) development of a new seed treatment formulation; (b) trial and selection of disease resistant cultivars; (c) formulation of suitable herbicide combinations; (d) development of a soil indexing procedure; (e) improvement of tillage practices; (f) adoption of interseason green manure crops and (g) modification of soil pH. The success of this integrated disease control program has brought pea root rot under control and increased pea yield by 150% over a three-year (1984 to 1986) period.

INTRODUCTION

Approximately 9,000 ha of green peas were planted each year[5]. A survey of 550 ha showed that root rot disease affected about 26% of the plant population. Many fields sustained total loss. Average pea yields in Ontario in 1983 were only 1.5 t/ha, where a yield of 5.0 t/ha is possible if root rots are brought under control[6].

The etiology of pea root rots in southwestern Ontario has not been fully resolved. There are more than 20 different fungi that can cause pea root rot[3]. Root rot disease of peas in different regions of the world may be caused by different fungi as a reslut of geographical and environmental differences. In Canada the most frequently isolated root rot fungi of peas have been *Fusarium solani* (Mart., Appel & Wr.) f. sp. *pisi* (F. R. Jones, Snyd. & Hans.), *F. oxysporum* (Schlect.) f. sp. *pisi* (Snyd. & Hans.) and *Pythium* spp., with *Asochyta pinodella* L. K. Jones and *Rhizoctonia solani* Kuhn isolated occasionally[7,20]. *F. solani* has been reported to be the predominant root rot fungus in southern Ontario[7], unfortunately, these reports have been based upon limited surveys. The frequency of isolation of specific pathogens has not been reported, nor the relative severity of disease caused by different root rot fungi. No recent systematic research efforts have been attempted on pea root rot in Ontario, so that new information is needed to develop an integrated control program (ICP) for the Ontario pea root rot complex. A detailed survey and controlled experiments are required to obtain information with respect to etiology, and biology of this disease complex.

This paper discusses the application of a quantitative approach toward etiological determination and application of biological findings in the development of integrated disease control measures.

MATERIALS AND METHODS

Etiology

A survey was conducted in Essex and Kent counties in southwestern Ontario. Totals of 600 and 800 ha were surveyed in 1983 and 1984, respectively. The acreages represented 50 and 75% of the total acreage of the largest pea processing company in the area. Since peas were grown exclusively for the company on contracts, the growers' fields to be surveyed were selected randomly from lists provided by the company.

Surveys were conducted between late May and mid-June each year. For each field, four replications of 10 plants were dug up and the incidence and severity of root rots were assessed. The severity was determined using a 0 to 4 scale in which 0 = healthy, 1 = 0-10%, 2 = 11-25%, 3 = 26-50% and 4 = 51-100% of the root discolored.

A large scale isolation was conducted in 1983 in conjunction with the disease survey. A total of 465 samples was collected randomly from 33 pea fields. Isolations were made by cutting small pieces (ca., 1 mm^3) of discolored root tissue. The tissue pieces were surface sterilized in 1.65% sodium hypochloride solution for 1 min, rinsed in distilled water and placed on an agar plate containing potato dextrose agar (PDA) and 40 μg /mL of novobiocin. For each petri plate, 4 pieces of tissue were plated. The plates were incubated at 22℃. After a 4-day incubation, the fungi that grew out of the tissue pieces were isolated and later identified on the basis of pathogenicity to a series of differential pea cultivars[16].

Development of a new seed treatment formulation

The etiology of this disease complex has been resolved and is reported later in the results section. Frequencies of isolation of *F. solani, F. oxysporum, Aphanomyces euteiches* and *Pythium* spp., were 7:4:1:1. It becomes apparent that *Pythium* and *Aphanomyces* are not a major component of this disease complex and should be controlled by seed treatment. Unfortunately, captan is the only chemical routinely used in treating pea seeds. Since captan cannot control Phycomycetous fungi, such as *Pythium* and *Aphanomyces*[23] other chemicals should be sought.

Several fungicides were assayed in the laboratory against *Pythium ultimum* and *Aphanomyces euteiches.* They were: benalaxyl, Dowco-444, metalaxyl, Ortho-Xe779, propamocarb, Re 26745 and oxadixyl. Two concentrations of fungicides were used, 40 μg a.i. /mL and 100 μg a.i./mL (Fig. 1). The fungicides were mixed into potato dextrose agar (PDA) which was plated in 10-cm petri plates. Small mycelial discs, 5 mm in diameter were punched from the actively growing colonies of *P. ultimum* and *A. Reuteiches* on PDA and transferred to the fungicide containing PDA, one disc per plate. For each fungus-chemical-dosage combination 4 replicated plates were prepared. The diameter of the colony was measured daily for one week. The experiment was repeated.

Seeds of the cultivar GG313, a wrinkle-seeded pea, were used throughout the test. Three fungicide dosages were used (i.e. 15, 30 and 60 g a.i./100 kg of seeds). The seeds and the fungicide were poured into a seed tumbler and a small amount of water was added. The seeds were tumbled for several minutes until they were evenly coated with the fungicide. Treated seeds were planted in potted soil obtained from a field with heavy root rot infestation, 100 seeds/25 cm pot at a depth of 2 cm below the soil surface. Four pots were planted for each dosage-chemical combination. After sowing, the pots were kept in a greenhouse at 21 ± 2℃ and watered as required. Germination counts and root rot ratings were made 2 and 4 weeks after sowing, respectively. Root rot severity was determined on a 0-9 scale, in which 0 = less than 10% of root with symptoms, 1 = 10-20% of root with symptoms, etc., 9 = plant dead. This rating system (0-9 scale) was also used in all experiments unless otherwise stated.

Based on the above evaluations, chemicals that were effective against *Pythium* and/or *Aphanomyces* and had no apparent phytotoxicity were selected. Metalaxyl and oxadixyl were selected for *Pythium* and Dowco-444 and benalaxyl for *Aphanomyces.* Three new formulations were developed in combination with captan. They were (a) captan, benalaxyl and metalaxyl; (b) captan, Dowco-444 and oxadixyl, and (c) captan, Dowco-444 and metalaxyl. To test their efficacy, each chemical was applied at three dosage levels (15, 30 and 60 g a.i./100 seeds). The treated seeds were planted in the same manner as described previously in the seed germination tests. Germination and root rot severity were determined as described above.

Trial and selection of resistant cultivars and lines

Most cultivars used in Ontario are highly susceptible to Fusarium wilt and root rot. An evaluation of a range of commercial cultivars and breeding lines for resistance to the Ontario root rot complex was conducted including cultivar trials, testing for specific resistance to Fusarium wilt and for non-specific resistance to Fusarium root rot. Although some pathotypes of *F. solani* have been reported[8], it is felt that the species is not yet

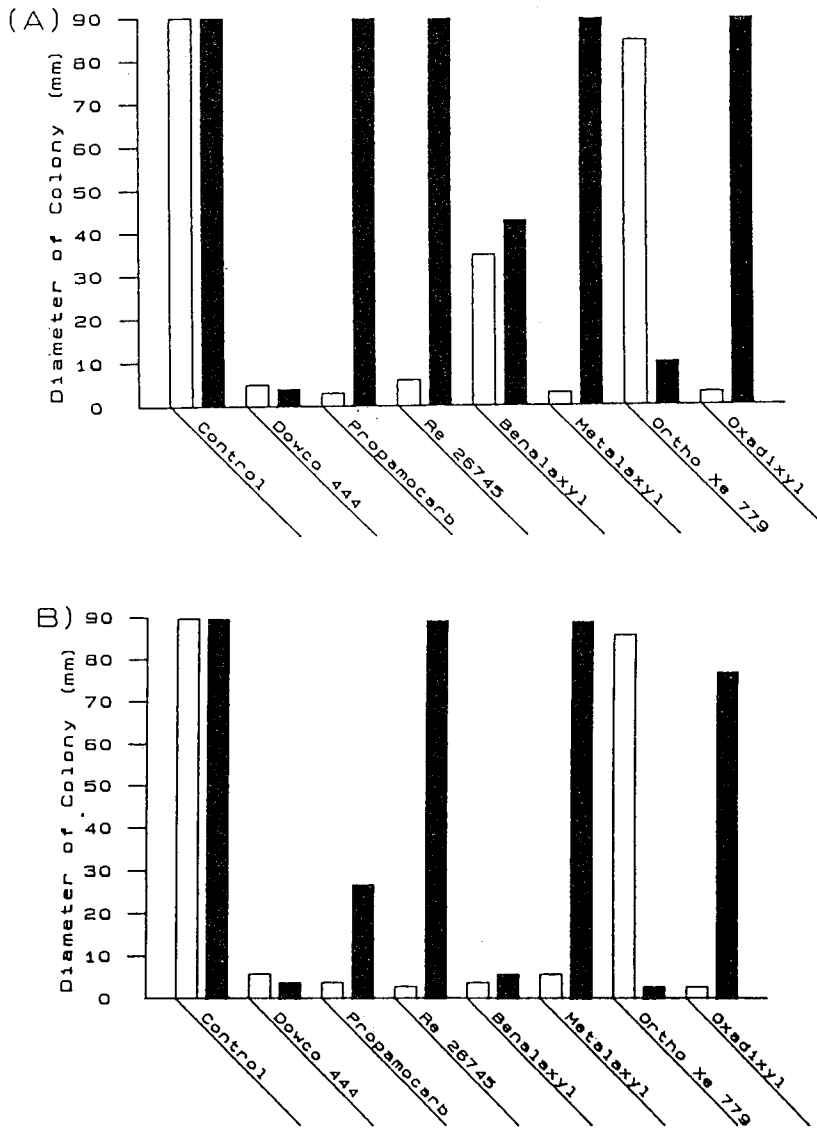


Fig 1. Effect of various fungicides on growth of *Pythium ultimum* (white bar) and *Aphanomyces euteiches* (black bar). Two concentrations of fungicides were used, 40μg a.i./mL (A) and 100 μg a.i./mL (B).

highly specialized.

Cultivars of peas were obtained from various research organizations and seed companies between 1983 and 1986. Each year, between 150 and 200 cultivars and lines were tested in 4 replications of randomized single rows in a field with severe root rot infestations. The ratio of Fusarium wilt and Fusarium root rot was approximately 7:4.

Root rot severity was rated on a 0-9 scale in the last week of June, with 20 plants examined in each row. Cultivars and breed-

ing lines which had a disease severity rating of 0 to 4 should have a high to moderate resistance to the disease complex of Fusarium wilt and root rot.

Formulation of suitable herbicide combinations

MCPB, MCPA and MCPA/MCPB (1:15), phenoxy compounds, are the most commonly used post-emergent herbicides for peas in Ontario. These herbicides have been found to increase root rot severity and exacerbate symptom expression[27]. Twelve herbicide treatments consisting of different combinations, rates and methods of application (see Table 9) were evaluated over a 3-year period. A moderately infested field in which a standard susceptible cultivar, (GG 512), usually showed in 100% infection with a disease severity rating of approximately 5.0 in a 0-9 scale was used. Herbicides were applied in accordance with the manufacturers' recommendations. Preplant incorporation were applied immediately before sowing, post-emergent spraying was applied about 4 weeks after sowing. Peas were sown each year in the first week of May. The 12 herbicide treatments and a control were randomized in each of 4 replicate blocks. A treatment plot consisted of 20 rows, 7 m long and 20 cm apart with 40 seeds/m. Root rot were rated on or about June 24 as weather permitted. In each test plot, 40 plants were scored on a 0-9 scale.

Development of a soil indexing procedure

F. oxysporum and *F. solani* are soil inhabitants. Incidence and severity of root rots are related to the density of inoculum in the soil, and fields with a previous history of root rot are likely to have an ongoing problem when susceptible cultivars are planted. Sherwood and Hagedorn[21] have developed a soil indexing method for common root rot (*A. euteiches*) of peas. This method was adapted to estimate the inoculum density of the predominantly *F. solani* and *F. oxysporum* in Ontario fields. However, the method proved to be laborious and costly. As an alternative, an on-site testing program was developed to evaluate the recommended cultivars in a small area of growers' fields one year prior to commercial production.

Improvement in tillage practices

Soil compaction increases incidence and severity of root rots[12,28]. Therefore, the effect of various tillage practices was investigated.

The field experiments were conducted on Brookston clay, a fine textured soil classed as an Orthic Humic Gleysol. This soil type, one of the most widely distributed in southwestern Ontario, has shown favorable response in yield when soil compaction is reduced[9].

A Latin square design was used to compare five tillage treatments planted in a east-west direction with green manure treatments superimposed running north-south.

The experiments were conducted in a field previously showed 100% disease incidence and an average disease severity of 8-9 on a 0-9 scale.

The five tillage practices applied were:

(1) Fall plough + spring flat seed bed preparation (FP);
(2) Fall plough + spring flat seed bed preparation + compaction (FPC);
(3) Fall plough + fall flat seed bed preparation (FP-FSBP);
(4) Fall chisel plough + spring flat seed bed preparation (CP);
(5) Fall plough + spring raised seed bed (20-cm in height) preparation (FPB).

The fall tillage practices were carried out in late October, and the plots left until mid-

April of the following year. Spring seed bed preparation involved smoothing the land with a triple-K. Soil compaction was achieved by running tractor wheels over the plots. Compacted and non-compacted fields had penetrometer readings of 11.0 and 18.0 kg pressure at 18 cm depth respectively using a Bush Recording Soil Penetrometer (Findlay & Irvine Ltd., Midlothian, Scotland).

Peas (cv. GG512) were planted each year in the first week of May. Pea root rot ratings were recorded in the third week of June. For each rating, 4 replications of 10 plants per plot were examined. The experiments were continued for 3 years (1984-86). The weight of pea plants were recorded at the same time.

Adoption of interseason green manure crops

The root rot disease complex that causes severe loss in this area can be attributed to long term improper cultural practices. One potentially beneficial practice is the growing of interseason green manure crops. At present, this is not widely practiced. The impact of interseason green manure crops in pea root rot disease control was investigated along with tillage practices using a Latin square design.

Bean, peas, rye, oats, corn, sudan grass and sorghum were grown as interseason green manure crops in two root rot-infested fields (one heavily and the other moderately infested). Immediately following the pea harvest in mid-July, the fields were chisel ploughed, disced, smoothed and sown to green manure crops. Cultivars of green manure crops, seeding rates and row width are listed in Table 1. At the end of October, samples were taken from each crop to estimate the amount of green manure production. Later, the green manure crops were chopped and incorporated into the soil.

In early May of each year, a root rot susceptible cultivar of pea (cv. Green Giant 512) was planted in 15 cm rows in both heavily infested and moderately infested fields. A randomized block design was used. There were four replications of each test. Root rot severity and pea growth were determined in the third week of June and first week of July, respectively, using a 0-9 scale. For pea growth, plants were sampled for fresh weight determination. For each plot four replications of 10 plants were sampled.

Effect of soil pH on root rots

i) *Effect of liming on plant growth, root rot severity and pea yield in a green manured and non-green manured soil*

A split plot design with 4 replicates was employed to compare green manured and non-green manured soil relative to quantity

Table 1. Cultivar and seeding rate of various green manure crops

Crop	Cultivar	Row width (cm)	Seeding rate (kg/ha)
Pea	Green Giant 512	15	246
Bean	Improved Tender Green	60	90
Rye	Empire	15	108
Sorghum	Silo Maker	15	81
Oats	Garry	15	100
Corn	Pioneer 3707	60	22
Sudan grass	Trudan 8	15	81

of liming. After the pea harvest in early July, one half (24 × 10 m) of each plot (approx. 24 × 20 m) was planted with field corn (cv. Pioneer 3707) at 60 cm row width and 22 kg/ha seeding rate and the other half left bare. In mid October, 1986, the corn plants were chopped. The yeild of green manure was estimated to be 8.8 t/ha. Immediately after, the plot was strip (3 m wide) limed by spreading dolomitic lime at a rate of 0, 0.5, 1.0, 2.0, 3.0, and 4.0 tonnes per ha and then disced to thoroughly incorporate the lime and green manure into the soil. The plot was left over the winter and planted with pea (cv. G.G. 512) in the first week of May, 1987. Fresh weight of plants, root rot severity, green pea yield and soil pH readings were recorded in the third week of June.

ii) *Effect of liming on soil microbial activity in a green manured and non-green manured soil*

In early July, soil samples were taken in four replications from the top 10 cm of soil with a core sampler. A series of dilutions (10^{-1} to 10^{-6}) were prepared from each soil sample. For bacterial count, 0.01 of a dilution was applied to a PDA plate. The plates were incubated at 22℃ and colonies were counted 48 h later. For fungal count, 0.01 of a dilution was applied to a PDA plate containing 40 μg/mL of tetracycline. The plates were incubated at 22℃ and fungal colonies were counted 72 h later. Root rot fungi were visually differentiated from other saprophytic fungi recognizing that a margin of error exists with this method of determination. Each dilution was plated four times.

iii) *Effect of different green manure on soil microbial activity*

Soil that was heavily infested with pea root rot fungi was brought into the greenhouse from the field in Tecumseh. The soil was limed with dolomitic lime to bring its pH to 6.5, an optimal pH for microbial activity determined in previous experiments[25]. The soil was divided into eight subsamples. One subsample was reserved as an untreated control and the other seven were allotted to seven different green manures (i.e. pea, bean, rye, sorghum, oats, corn and sudan grass). The green manures were harvested from the filed, oven derived at 55℃ and ground in a Mill grinder with a 2 mm^2 screen.

Two percent by weight of each type of ground dried green manure was added to each soil preparation, throughly mixed in a cement mixer and placed in 13 cm-pots. No dried green manure powder was added to the control. Each treatment consisted of eight replicated pots. The pots were kept constantly moist in a greenhouse at 22 ± 2℃ for a six month digestion. Later, the pots were divided into two groups. One was planted with peas (cv. G.G. 512) to assess the severity of root rots and the other was used for soil sampling to determine the soil microbial population using a method described previously. Root rot severity of pea was scored two months after sowing.

RESULTS AND DISCUSSION

Etiology

Root rot survey. The incidence of pea root rot varied widely from field to field and differed greatly from one cultivar to the other. Variation among fields ranged from 0 to 98.5% and cultivars from 15.8 to 53.5% (Table 2). Similarly, the disease severity also varied widely among cultivars. For example, GG451 had an average root rot severity rating of 1.6 versus a 3.3 rating for GG 313 on a 0 to 4 scale (Table 2). The differences in incidence and severity among pea cultivars indicate that some cultivars may be more tol-

erant to one or more root rot pathogens.

Isolation of root rot organisms. Isolations were prepared from 465 samples collected from 33 pea fields, from which 782 fungal cultures were isolated. Of the 782 fungal cultures, 356 were *Fusarium solani,* 201 were *F. oxysporum,* 58 were *Aphanomyces euteiches,* 48 were *Pythium* spp. (mostly *P. ultimum*), 6 *Rhizoctonia solani,* 5 *Thielaviopsis basicola* and the remainder (108) were non-pathogenic fungi, mostly common soil inhabitants. Frequencies of isolation of *F. solani, F. oxysporum, Aphanomyces euteiches* Drechs and *Pytium* spp. were 7:4:1:1[24]. Other fungi, e.g., *R. solani, A. pinodella* and *Thielaviopsis basicola* (Berk. & Br.) Ferraris, were isolated only occasionally.

Overall disease severity and yield loss are the sum of the effects of each component fungus. The incidence of pea root rot in southern Ontario averaged 26.5%. Disease severity of each root rot was determined on a scale of 0 to 9. The severity of disease caused by *F. solani* (root rot), *F. xysporum* (wilt), *Pythium* and *Aphanomyces* averaged 3.2, 8.7, 2.6, and 40, respectively. Isolates of *F. oxysporum* were identified as races 1 and 2 by a differential scheme[12] and known races provided by J. M. Kraft of Prosser, Washington. The ratio of race 1 to race 2 was 7:4.

Table 2. Incidence and severity of pea root rot in 1983 and 1984 in Essex and Kent counties

Cultivar	Area (ha)						Root rot			
	Total		Surveyed		% Surveyed		Incidence (%)		Severity[1]	
	1983	1984	1983	1984	1983	1984	1983	1984	1983	1984
E.J. 235	92.7	90.9	45.9	67.7	50.0	73.6	53.5	34.1	2.1	2.7
Sparkle	131.8	66.4	80.5	48.2	60.6	72.7	15.8	21.1	3.2	2.8
Mini 381	207.7	135.0	111.4	99.5	53.6	74.1	21.3	22.8	2.0	2.1
G.G. 313	188.2	—[2]	74.5	—	39.9	—	43.3	—	3.3	—
G.G. 451	10.0	422.0	0.0	320.0	0.0	75.8	NA	20.2	NA	1.6
G.G. 512	387.3	307.0	222.3	248.2	57.3	80.8	20.7	21.1	2.2	1.8

1) Root rot rating based on a scale of 0-4 in which 0 = healty, 1 = 0-10%, 2 = 11-25%, 3 = 26-50% and 4 = 51-100% of the root discolored.

2) Cultivar discontinued in 1984.

On the basis of this information, and assuming that hosts, environmental conditions, and cultural practices are random relative to isolation, a simple disease damage index (DDI) can be developed to rank the root rot fungi according to etiologic importance. The DDI of a root rot equals the total amount of root rot × the frequency of occurrence of each root rot fungus × the severity of disease caused by each fungus. The DDIs (Table 3) show that Fusarium wilt is the most serious problem, followed by Fusarium root rot. Plants with Fusarium wilt usually die, whereas plants with Fusarium root rot show various degrees of stunting and yellowing and droopy in warm, sunny afternoons, but rarely die. *Pythium* and *Aphanomyces* root rots are minor problems in Ontario.

Development of a new seed treatment formulation

Bioassay of various fungicides against *P. ultimum* (Pu) and *A. euteiches* (Ae) showed

Table 3. Disease damage index (DDI) of each fungus in the Ontario root rot complex (average incidence = 26.5%)

Fungus	F.O.[1)]	D.S.[2)]	DDI
Fusarium solani	7/13	3.2	45
F. oxysporum	4/13	8.7	71
Pythium spp.	1/13	2.6	5
Aphanomyces euteiches	1/13	40.0	8

1) Frequency of occurrence.

2) Disease severity, based on a 0-9 scale, in which 0 = <10% of root with symptoms, 1 = 10-20% of root with symptoms, 9 = plant dead.

that Pu was sensitive to Dowco-444, propamocarb, RE 26745, metalaxyl, oxadixyl and benalaxyl (Fig. 1). Ae, however, was sensitive only to Dowco-444, RE 26745, Ortho-Xe 779 and benalaxyl (Fig. 1).

Although Pu and Ae are both phycomycetous fungi, they differ in their sensitivity to chemicals. Of the above chemicals Dowco-444, RE 26745 and Ortho-XE 779 are still in the experimental stage of development and the availability of propamocarb is limited. In addition, Ortho-XE 779 had an adverse affect on seed germination (Table 4). Therefore, benalaxyl and metalaxyl were chosen for Ae and Pu, respectively.

All above fungicides had some residual effect in controlling root rot as compared with untreated control (Table 5). The residual effect was more apparent for Ortho-XE 779, propamocarb, oxadixyl and RE 26745 than metalaxyl and captan (Table 5).

It must be pointed out that the high root rot indices were expected, because the residual effects of seed treatment fungicides were limited. GG 313 is a highly susceptible cultivar to root rot and they were grown in a soil with high inoculum density.

Three new formulations were developed and evaluated. These were: (a) captan-benalaxyl-metalaxyl, (b) captan-Dowco-444-oxadixyl and (c) captan-Dowco-444-metalaxyl Seeds treated with any of the 3 formulations gave significantly higher percentage of germination and somewhat lower root rot severity than untreated control (Table 6).

These results suggest that addition of fungicide specific to phycomycetous fungi to captan for seed treatments is desirable. Seed

Table 4. Effect of fungicides on seed germination

	% germination of treated seed[1)]							
g fungicide per 100 kg seed	Control untreated	Captan	Xe-779	Oxadixyl	Propamocarb	Metalaxyl	Re 26745	Dowco-444
15	64.0	73.0 a	43.3 a	81.0 a	82.5 a	69.3 a	81.0 a	78.5 a
30	64.0	70.5 a	35.3 b	77.5 ab	76.5 b	73.5 a	78.0 a	70.5 b
60	64.0	71.3 a	28.3 c	75.3 b	71.3 c	77.8 a	78.5 a	74.5 ab

1) Means within columns followed by the same letter are not significantly different (P > 0.05) according to Duncan's multiple range test.

Table 5. Root rot severity in 4 week-old plants grown from seeds treated with different fungicides (60 g a.i./100 kg seed for each chemical)

Fungicide	Severity of root rot (0-9 scale)[1)]
Control (not treated)	8.8 a[2)]
Captan	7.6 b
Ortho Xe-779	7.7 b
Propamocarb	6.4 c
Metalaxyl	7.2 bc
Dowco-444	6.4 c
Oxadixyl	6.4 c
Re 26745	6.4 c

1) See footnote of Table 3.
2) See footnote of Table 4.

Table 6. Comparison of the 3 new seed treatment formulations on seed germination and root rot severity on 4-week-old plants.

g fungicide of each component per 100 kg seeds		Captan benalaxyl metalaxyl	Captan Dowco-444 oxadixyl	Captan Dowco-444 metalaxyl
15	Seed	77.5 a[2)]	80.0 b	71.8 a
30	germination	81.0 b	74.5 a	84.0 c
60	(%)	78.8 a	83.8 c	82.0 b
15	Root rot	8.2 c	8.5 c	8.5 c
30	severity	7.8 b	8.0 b	8.1 b
60	(0-9 scale)[1)]	7.1 a	7.3 a	7.5 a

1) See footnote of Table 3.
2) see footnote of Table 4.

treatment with the new formulations increased seedling stand by an average of 24 to 31% and 13 to 18% over untreated control and captan treated seeds. Seed treatment alone cannot control root rots of peas, but it may form a component of an integrated control program.

Trial and selection of disease resistant cultivars

The results (Tables 7 and 8) showed that many commercial cultivars and breeding lines had a disease severity rating of 0 to 4. These results indicated that these cultivars and lines had a high to moderate resistance to the disease complex of Fusarium wilt and root rot in Ontario.

These resistant cultivars (Table 7) could be adopted readily into commercial production in southwestern Ontario. Many of the resistant breeding lines (Table 8) could be developed into new cultivars or used in breeding for disease resistance.

All cultivars and breeding lines which had a rating of 4.1 to 9.0 were moderate to

Table 7. Response of cultivars to the disease complex of Fusarium wilt and root rot of peas in southwestern Ontario[1)]

Root rot severity Index (0-9 scale)[2)]	Cultivar[3)]				
0-1.0	Perfection WR[1]				
1.1-2.0	Early Perfection[2]	RS-7[3,4]	Parlay[2]	Green Giant 531 (Nuttall selection)[1]	
2.1-3.0	New Season[2]	Anoka[2]	Novella[2]	Almotto[2,4]	Puget[2]
	Bolero[5,6]	Medalist[6]	M140[2]	Early Perfection 3040[2,4]	
	Home Guard[1]				
3.1-4.0	Frontier[7]	Parlay[8]	Alaska 423[9]	Early Forsty[2]	Mini[2]
	Maro[2]	Little Sweetie[11]	Massette[10]	Jade[2]	M-129[1]
	Olympia[12]	Mercurio[10]			

1) This list may include some private cultivars and named breeding lines. Interested parties who wish to obtain seeds should write directly to their respective sources.
2) For 0-9 scale, see footnote of Table 3. Cultivars having a rating higher than 4 are not listed.
3) The superscripts following each cultivar indicate the suppliers of seeds: 1: Mr. V. W. Nuttall (deceased), Harrow Resarch Station, Ontario; 2: Dr. R. J. Howard, Alberta Horticultural Research Center, Brooks, Alberta; 3: Dr. T. P. Reiling, Pilllsbury Co. Le Sueur, Minn.; 4: Dr. J. M. Kraft, Irrigated Agriculture Research and Extension Center, WN.; 5: Libby Co., Ontario; 6: Asgrow Seed Co., MI; 7: Canadian Canners Ltd., Ontario; 8: Roger Bros. Seed Co., Ontario; 9: Dr. A. A. Reyes, Vineland Research Station, Ontario; 10: Del Monte, California; 11: Stokes Seeds Ltd., Ontario; 12: Harris Moran Co. Seed, Ontario.

highly susceptible and were excluded from the tables.

Formulation of suitable herbicide combinations

Some herbicides increased, some had no effect and some reduced the severity of pea root rot (Table 9). Herbicides that reduced root rot were: (a) pendimethalin, (b) cyanazine, (c) pendimethalin + cyanazine, (d) trifluralin + cyanazine and (e) oryzalin + trifluralin. These are all dinitroaniling compounds except the triazine, cyanazine. In the triazine group, prometryne appears to be neutral with respect to root rot severity. Benzoic acid (chloramben) and phenoxy compounds (MCPA and MCPB) generally increased the severity of root rot in peas.

Dinitroaniline and dinitramine herbicides that reduce root rots caused by phycomycetous fungi[2,10,15] have been shown to disrupt the flagella of zoospores[22]. Since most fields in Ontario have a very highdensity of *Fusarium* spp. and a negligible amount of *Pythium* spp.[20], the reduction in severity of pea root rot by these treatments may be attributable to some other factor.

The phenoxy compounds (MCPA, MCPB and MCPA/MCPB) are somewhat similar in structure and function to 2,4-D and are plant growth regulators[4], while the dinitroaniline and dinitramine herbicides are inhibitors of protein synthesis and tend to reduce root elongation[4].

Development of a soil indexing procedure

Table 8. Response of breeding lines to the disease complex of Fusarium wilt and root rot of peas in southwestern Ontario.[1)]

Root rot Severity Index (0-9 scale)[2)]	Line[3)]				
1.1-2.0	9602-10 a	97067-1-5-1 a			
2.1-3.0	80-717 cd	7710-4-1-2 a	9731-3 a	X9602-7 a	494-All bc
	7801-10-3 a	X9500-1-1 a	9601-3-7-2 a	9816-14 a	8221-5a
	9601-3-3 a	C82-409 e	9713-6-1 a	9713-30 a	7601-2-1-4 a
	X9725-8 a	X9504-2-3 a	74-SN5 b	WSU R22 bc	
	Minnesota 108 bcd				
3.1-4.0	7705-7 a	X9727-10 a	X9602-2 a	VR1492-1 bc	508-7a
	9603-10-12 a	89617-EP a	83-1356 f	7712-10 a	P.I.189171 bc
	9406-1 a	9728-8 a	83-1392 f	7025a	WR1158 f
	X9726-2 a	89171 b	9889-2 a	9888a	PH14-119 b
	7705-8 a	507-8 a	9716-1-1 a	OH69.22 g	8615-3EP a
	74-SN4 bc				

1) The list may include some numbered cultivars and private breeding lines. Interested parties who wish to obtain seeds should write directly to their respective sources.
2) For 0-9 scale, see footnote of Table 3. Lines having a rating higher than 4 are not listed.
3) The superscripts following each line indicates the suppliers of seeds: a: Dr. D. Polson, Canners Seed Co., Idaho; b: Dr. R. J. Howard, Horticultural Research Station, Alberta; c: Dr. J. M. Kraft, Irrigated Agriculture Research and Extension Center, WN.; d: Pillsbury Co. Le Sueur, Minn.; e: Roger Bros. Seed Co., Ontario; f: U.S.D.A., Beltsville, Md.; g: Mr. V. W. Nuttall (deceased), Harrow Research Station, Ontario.

Table 9. Effect of different herbicides on the severity of root rot of peas grown in soil with moderate fungal infestation

Treatment	Rate (kg/ha)	Application	Root rot severity (0-9 scale)[2)]
Control			5.2 b[3)]
chloramben	3.0	Pre[1)]	6.1 c
cyanazine	2.0	Pre	4.4 a
pendimethalin + cyanazine	2.0	Pre	4.4 a
prometryne	2.2	Pre	5.1 b
trifluralin; MCPA	0.8; 0.4	Ppi; Post	5.9 c
trifluralin; MCPB (Tropotox)	0.8; 1.7	Ppi; Post	7.3 d
trifluralin; MCPB (Thistrol)	0.8; 1.7	Ppi; Post	7.4 d
trifluralin; MCPA/MCPB	0.8; 1.7	Ppi; Post	7.6 d
oryzalin	0.8	Ppi; Post	6.2 c
pendimethalin	2.0	Ppi	4.3 a
trifluralin + cyanazine	0.8 + 1.5	Ppi	4.0 a
oryzalin + trifluralin	0.4 + 0.4	Ppi	4.3 a

1) Per = pre-emergent spray, Ppi-preplant incorporation and Post = post emergent spray.
2) A three-year average. For 0-9 scale, seed footnote of Table 3.
3) See footnote of Table 4.

Soil indexing conducted in pots in the greenhouse and in short rows in the field was equally effective. In fact, the variation in disease severity was smaller in the field than in the greenhouse. In-field soil indexing allowed the testing of more cultivars, so that in-field soil indexing was preferred in practical farming operations.

Improvement in tillage praction

Tillage practices played an important role in root rot severity in root rot infested fields. The results of 1985 and 1986 were generally similar and only 1986 data are presented (Table 10).

Most of the variation among the tillage practices could be associated with the comparison of treatments 1, 2 and 3 with treatments 4 and 5. FPB and CP had lower incidence of root rot and FPC gave the highest root rot severity.

Adoption of interseason green manure crops

Effect of green manure on root rot — The results (Table 11) showed that even one interseason of green manure incorporation in the fall of 1983 effectively reduced the severi-

Table 10. Effect of different tillage practices on severity of pea root rot in fields with heavy root rot infestation.

Tillage practice	Root rot severity (0-9)[1]	Fresh wt of plants (g) (40 plants)
1. Fall ploughing + spring seedbed (FP)	7.7 b[2]	78.6 c
2. Fall ploughing + compaction (FPC)	8.0 bc	29.6 e
3. Fall ploughing + fall seedbed (FP-FSBP)	7.5 b	58.4 d
4. Chisel ploughing + spring seedbed (CP)	7.0 ab	88.4 b
5. Fall ploughing, raised beds (FPB)	6.4 a	115.4 a

1) For 0-9 scale, see footnote of Table 3.

2) See footnote of Table 4.

Table 11. Effect of 1, 2 and 3 years of interseason green manure crops on root rot severity of peas in fields with heavy root rot infestation.

Green Manure Crop	Root rot severity (0-9)[1]		
	1984	1985	1986
Control (none)	7.0 b[2]	7.3 c	7.8 c
Peas	8.8 c	8.6 d	8.7 d
Beans	7.3 b	7.4 c	8.2 d
Rye	7.0 b	6.8 bc	7.4 c
Oats	6.2 a	5.8 a	5.5 a
Sorghum	6.0 a	6.5 b	5.6 a
Corn	6.8 b	6.5 b	6.4 b
Sudan grass	6.8 b	6.3 b	6.4 b

1) For 0-9 scale, see footnote of Table 3.

2) See footnote of Table 4.

ty of the root rot disease in the subsequent pea crop in 1984. Of the seven green manure crops employed, peas and beans resulted in a slight increase in disease severity, particularly peas. Rye had little or no effect but the other graminaceous species (oats, corn and sudan grass and sorghum) reduced root rot severity significantly, with oats the most effective.

When the same green manure procedure was repeated for the 2nd and 3rd years in heavily infested fields, pea root rot severity in plots with oats, corn, sudan grass and sorghum as green manure showed a gradual but steady decline over the years. In contrast, plots with beans, peas and rye as green manure showed either a slight increase or remained unchanged. The pea root rot severity in control plots also increased slightly.

Effect of soil pH on root rots. A field survey showed that there were no significant differences in root rot severity relative to soil pH; however yield was related to soil pH. The most favorable soil pH for pea yield was between pH 5.9 and 6.4. Acceptable yields were obtained between pH 5.4 and 5.9 and pH 6.4 and 7.0 while pH values below 5.4 were unfavorable (Table 12).

i) *Effect of liming on plant growth, root rot severity and pea yield in a green manured and non-green manured soil in the field*

Liming a heavily root rot infested field with various amounts of dolomitic lime resulted in increase of soil pH from an unlimed check of pH 5.5 to a maximum of pH 7.2. Plant growth and yield on green-manured and non-manured soils responded differently to soil pH. The greatest plant growth and green pea yield were found between pH 5.9 and 6.5 in non-green manured soil and pH 6.5 and 7.0 in green manured soil. Increase and decrease in soil pH from the optimal ranges resulted in a gradual decrease in plant growth and pea yield (Table 13). Root rot severity responded to liming somewhat similarly to plant growth and pea yield, but the ranges were considerably smaller (Table 13). An apparent synergistic interaction existed between green manuring and liming. For example, at optimal soil pH (6.5), plant growth and pea yield in green manured soil increased approximately 30 to 40% over the non-green manured soil. The favorable pH range for plant growth in green manured soil was broader (pH 6.5-7.2) than those (pH 5.9-6.5) in non-green manured soil (Table 13).

ii) *Effect of liming on soil microbial activity in a green manured and non-green manured soil in the field*

Although the soil pH increased as lime was added to the soil, the increases in soil pH were not proportional to the amount of lime added (Tables 12 and 13). There was a significant interaction between green manuring and liming in terms of microbial population in the soils.

Table 12. Relationship between soil pH and severity of root rot

pH	<5.0	5.0-5.4	5.5-5.9	6.0-6.4	6.5-6.9	7.0
No. of field	1	11	26	12	9	4
Ave. pH	4.85	5.30	5.74	6.28	6.75	7.11
Ave. root rot (0-4 scale)	0.9 a[1)]	2.0 b	1.8 b	19 b	2.3 b	2.5 b
Ave. yield of pea (kg/ha)	2,344 a	2,976 b	3,327 c	4,083 d	3,092 b	3,186 b

1) See footnote of Table 4.

Table 13. Effect of liming on soil pH, Plant growth, root rot and pea yield in a heavily root rot infested plot with or without green manuring with corn

Lime (tonnes/ha)	Soil pH (8 mo after liming)	Fresh wt of plant (g/10 plants)[1]		Green pea yield (g/10 plants)[1]		Root rot severity (0-9 scale)[2]	
		Green manured	Non-green manured	Green manured	Non-green manured	Green manured	Non-green manured
0	5.5	59a[3](a)[4]	54a(a)	24a(b)	20a(a)	7.3c(a)	7.1c(a)
0.5	5.7	71b(b)	56ab(a)	32b(b)	22a(a)	6.9bc(a)	6.8bc(a)
1.0	5.9	81b(b)	59b(a)	36bc(b)	25b(a)	6.5b(a)	6.9bc(b)
2.0	6.5	103c(b)	65b(a)	48d(b)	28bc(a)	5.1a(a)	5.8a(b)
3.0	7.0	97c(b)	53a(a)	42c(b)	19a(a)	6.2b(a)	6.6b(b)
4.0	7.2	95c(b)	50a(a)	38c(b)	19a(a)	7.3c(a)	78.6d(b)

1) Data were taken in the third week of June, approximately 8 months after liming.
2) Disease severity based on a 0-9 scale, see footnote of Table 3.
3) See footnote of Table 4.
4) (a)-(b) Means are compared between green manured and non-green manured soils. The figures which bear the same letter are not significantly different ($P>0.05$) according to Student's t test.

In non-green manured soils, an increase in soil pH from 5.5 to 7.0 resulted in a gradual increase in soil bacterial population but there was a slight decrease between soil pH 7.0 to 7.2. On the other hand, populations of both saprophytic and root rot fungi decreased gradually as soil pH increased from 5.5 to 7.2. The population of saprophytic fungi appeared to decrease more quickly than those of root rot fungi.

In green manured soil, an increase in soil pH from 5.5 to 7.2 drastically increased the bacterial popultaion in the soil by approximately 20-fold. The population of both saprophytic and root rot fungi decreased with higher soil pH except for an increase was observed between pH 5.5 and 5.7 for saprophytic fungi. The decrease in fungal population occurred more sharply for root rot fungi than saprophytic fungi.

Comparisons of microbial population in limed soil with or without green manure showed that the soil bacterial population drastically increased and fungal populations (both saprophytic and root rot) decreased in the green manured and limed soil. The decrease was greater for root rot fungi than saprophytic fungi in green manured soil. In non-green manured soil, however, the decrease was greater for saprophytic fungi than root rot fungi (Table 14).

iii) *Effect of different types of green manure on soil microbial activity in a heavily root rot infested soil at pH 6.5 in the greenhouse*

The results (Table 15) showed that microbial population in the soil varied with the type of green manure used. The types of green manure that induced a large increase in soil bacteria tended to result in low root rot severity in peas. Green manure of the grass family (such as rye, sorghum, oats, corn and sudan grass) increased bacterial pupulation more than peas and beans used as green manure. The bacterial population after green

manuring with plants of the grass family were predominantly *Bacillus* spp. and fluorescent *Pseudomonas* spp. Althoug peas and beans also increased soil bacterial population, their increases were small compared with rye, sorghum, oats, corn and sudan grass. Moreover, the small increases in bacterial population by peas and beans were overshadowed by the increase in the population of root rot fungi which reesulted in increased root rot severity (Table 15).

Although liming of acidic soil reduced

Table 14. Effect of liming on soil pH and soil microbial activity in a heavily root rot infested plot with or without green manuring with corn

Lime (tonnes/ha)	Soil pH (8 mo after liming)	Microbial Population[1]					
		Non-green manured soil			Green manured soil		
		Bacteria (10^5/cm^{3}soil)	Saprophytic fungi (10^3/cm^{3}soil)	Root rot fungi (10^3/cm^{3}soil)	Bacteria (10^5/cm^{3}soil)	Saprophytic fungi (10^3/cm^{3}soil)	Root rot fungi (10^3/cm^{3}soil)
0	5.5	0.6a[2](a)[3]	2.3c(b)	2.7de(b)	1.7a(b)	2.1c(a)	2.2d(a)
0.5	5.7	0.9b(a)	2.2c(a)	2.4d(b)	3.1b(b)	2.6d(b)	1.8c(a)
1.0	5.9	2.0c(a)	2.1c(a)	1.9c(b)	10.4c(b)	2.4d(b)	1.4b(a)
2.0	6.5	4.2e(a)	1.0b(a)	1.5b(b)	36.2d(b)	1.6b(b)	0.8a(a)
3.0	7.0	4.4e(a)	0.7a(a)	1.5b(b)	35.4d(b)	1.2a(b)	0.6a(a)
4.0	7.2	3.5d(a)	0.8a(a)	1.2a(b)	34.6d(b)	1.3a(b)	0.6a(a)

1) Samples were taken 8 months after liming.
2) a-d See footnote of Table 4.
3) (a-b) Means within line of respective items (e.g. Bacteria vs. bacteria of non-green manured and green manured) followed by the same letter are not significantly different ($P>0.05$) according to Student's t test.

Table 15. Effect of different types of green manure on soil microbial activity in a heavily root rot infested soil at pH 6.5

Type of green manure	Ave. severity of root rot (0-9)[1]	Microbal population		
		Bacteria (10^5/cm^3 soil)	Saprophytic fungi (10^3/cm^3 soil)	Root rot fungi (10^3/cm^3 soil)
Control	7.2	10.7 a[2]	1.8 a	2.9 d
Pea	8.6	20.0 c	11.7 e	11.2 f
Bean	7.4	16.2 b	8.2 d	5.3 e
Rye	6.5	27.2 d	3.5 c	2.6 d
Sorghum	5.3	44.3 f	3.1 b	1.9 bc
Oats	4.8	64.2 g	3.0 b	1.1 a
Corn	5.5	42.2 f	3.2 bc	1.6 b
Sudangrass	5.4	38.0 e	2.8 b	1.8 bc

1) For 0-9 scale, see footnote of Table 3.
2) See footnote of Table 4.

root rot severity somewhat, the reduction was substantially enhanced with addition of green manure and crop residue of a species unrelated to the crop. Apparently crop residues increased saprophytic bacterial and fungal population which in turn increased soil organic matter. Tu[25] reported an organic matter content of 4% in soil (pH 5.5) which had been planted to peas for 3 consecutive years without interseason green manure. After 3 years of interseason green manure between July 15 to October 30 of each year an overall increase of 1% in soil organic matter was realized without liming of the soil. Experimental results would suggest that, with liming, organic matter in the soil will be increased further as a result of microbial activity.

The present results are consistent with other works[11,13,29] who showed that liming of acidic soils reduced the impact of Fusarium wilt and root rot. Garrett[14] showed that vascular wilts and cortical root rots caused by *formae speciales* of *F. oxysporum, F. roseum, F. nivale,* and *F. solani* are more severe in acidic soils. Cook and Baker[13] and Woltz and Jones[29] postulated that liming of acidic soil caused a reduction in micronutrients sufficient to restrict growth of the pathogen but not the plant.

In addition to liming, several researchers have used plant residues to control root rots. Papavizas[18] reported several situations in which biological control of a pathogen by plant tissues was related to reduction of the inoculum density of the pathogen. Addition of oat straw, corn stover, of alfalfa hay to *Thielaviopsis basicola*-infested soil caused a population reduction of about 90% and almost colmplete elimination of the root rot of bean caused by the pathogen. The population reduction was attributed to the stimulation of germination of endoconidia and chlamydospores of *T. basicola,* with subsequent germling lysis occurring before formation of secondary endoconidia or chlamydospores[1,18,19].

Lewis and Papavizas[17] observed in a greenhouse study that of the 10 kinds of plant tissues incorporated into soil, 9 significantly reduced bean root rot caused by *F. solani* f. sp. *phaseoli.* Mature plant residues were generally more effective than immature ones in reducing root rot. They believed that pathogen survival and destruction are intimately associated with the decomposition of a particular residue that appears to involve volatile and toxicant production, fungistasis, lysis, antagonism and antibiosis.

The present results show that combining liming and green manuring can enhance soil microbial activity. The high level of saprophytic bacterial and fungal activity indicates that antagonism and antibiosis may play an important role in the control of root rot disease. It must be emphasized that combination of liming and green manuring is superior to liming or green manuring alone.

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摘　要

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在渥汰華西南方豌豆根腐病之平均田間發病率爲 26%。複合感染引起的根腐病嚴重影響豌豆的產量。爲了解此病害之病因學，總共從 33 個豌豆田收集 465 個病害標本，進行 782 次的分離試驗，結果獲得 *Fusarium solani* f. sp. *pisi*, *F. oxysporum* f. sp. *pisi*, *Aphanomyces euteiches* and *Pythium* spp. 等病原菌，其比例爲 7:4:1:1。*F. oxysporum* 菌株中，race 1 及 race 2 的比例爲 7:4。*F. solani* 對寄主品種間較無選擇性，故未鑑定其生理小種。由 *F. solani*（根腐），*F. oxysporum*（萎凋），*Pythium* 及 *Aphanomyces* 引起的平均發病度（0～9 級的範圍）分別爲 3.2, 8.7, 2.6 及 4.0。通常，感染 *F. oxysporum* 之罹病株終將死亡，而罹患 *F. solani* 者僅表現不同程度之矮化與黃化病徵。另外 *Pythium* 及 *Aphanomyces* 僅少數發生。據此，發展一套病害損失指數（disease damage index, DDI）對上述四種病原菌之相對重要性加以分級。根腐病之 DDI 即是總發病率（26.5%）×病原出現率×病原引起之發病度。結果上述四種病原，*F. solani*，*F. oxysporum*，*Pythium* spp. 及 *A. euteiches* 之 DDI 依序分別爲 45、71、5 及 8。因此，*F. oxysporum* 最重要，*F. solani* 次之，而 *Pythium* 及 *Aphanomyces* 較不重要。基於對豌豆根腐病之病因學及生物學之研究，發展出一套綜合防治方法，包括 (a) 選用種子處理藥劑之新配方，(b) 種植田間抗病品種，(c) 處理適當的殺草劑配方，(d) 應用田間土壤指數的預測方法，(e) 改善耕犁方式，(f) 栽植適當的綠肥作物及 (g) 調節土壤 pH 值。本方法於 1984～1986 年之田間試驗表現能夠控制根腐病，並增產 150%。

土壤病原生態與防治研討會專刊 36～44, 1991

豌豆萎凋病之發生與防治

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摘　要

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本省豌豆主要採冬季裡作之糊籽栽培（冬季豌豆），與少數在其他季節種植於旱田採立支柱栽培者（夏季豌豆）。幼苗期發生由 *Fusarium solani* f. sp. *pisi* (Fsp) 引起根部腐爛，葉片黃化，以及偶而維管束呈磚紅色病變的根腐病，罹病株並不會死亡。進入開花期的成株，則發生由 *F. oxysporum* f. sp. *pisi* (Fop)引起半側葉片黃化，維管束褐化，終至萎凋死亡的萎凋病，尤以夏季豌豆發生最爲嚴重。萎凋病比根腐病重要。在中、南部豌豆栽培區，Fop 有 race 2 及 5 的分化。前者分佈較廣，出現頻率較高。Fop race 2 在培養基上易變異成粘膜型菌株，其毒性（virulence）與存活能力皆遜於野生種的胞叢型菌株。在冬季豌豆田，Fop race 2 分佈於耕犛層，受兩期水稻輪作淹水措施的影響，在土壤中之數目會下降至無法偵知，使隨後種植的豌豆不致嚴重被害。但土壤中的病原菌密度又會隨時間逐漸回升。其接種源可能源自豌豆種子，水稻及雜草根部或土壤顆粒中殘存者。使用種子保護劑，如得恩地 75% 可溼性粉劑（2 g/Kg 種子）拌入等量的粘著劑（graphite），對冬季豌豆具有初期保護作用，但對夏季豌豆無效。在夏季豌豆田使用氰氮化鈣（300 Kg/ha）則具有抑制萎凋病之效果。

（關鍵字：豌豆萎凋病，根腐病，生理小種，變異，存活，種子帶菌，土壤添加物，綜合防治。）

緒　言

豌豆（*Pisum sativum* L），俗稱荷蘭豆，由荷蘭人引入台灣[3]，早期僅零星栽培，近年卻擴大經營，外銷新鮮豆莢，成爲秋、冬季的重要經濟作物。依省府農業年報[12]，年總栽培面積已由以往的二千多公頃躍增至六～八千公頃左右，主要分佈於中、南部地區，採冬季裡作糊籽栽培方式（以下稱冬季豌豆）：即二期水稻收割後，不整地，挖穴直播豌豆種子，讓豆蔓匍伏於地上。另外，在旱地蔬菜田或高冷地區的較少數面積則種植於其他季節，採立支柱栽培方式（以下稱夏季豌豆）。栽培品種以“台中 11 號”、“台中 9 號”及“在來白花”爲主，尤其“台中 11 號”之園藝性狀優良，曾經佔總栽培面積之 65% 以上[8]。豌豆適宜冷涼乾燥氣候，生育適溫爲 15～20℃，中部地區的日平均溫度，在十一月份以後才會降至 20℃以下，才適合豌豆的栽培。但許多農友爲搶先市場價格而種植夏季豌豆，在高溫多濕的環境下，使得病害叢生，計有 9 種之多[4]。尤其以 *Fusarium oxysporum* f. sp. *pisi* Snyd. & Hans.（以下稱 Fop）所引起的萎凋病最爲嚴重。在田間，萎凋病卻常與由 *F. solani* f. sp. *pisi* Snyd. & Hans.（以下稱 Fsp）引起的根腐病形成複合感染[29,39]，是本省未經鑑定的重

要病害之一。有必要瞭解其病因學與生物學之特性，進而發展適當的防治方法。

病因學

在 1981～1986 年間，赴全省各地調查豌豆病害，發現農友所謂的“立枯病”嚴重發生，尤其更見許多非經水稻輪作的夏季豌豆田因而廢耕。豌豆幼苗罹患根部乾腐變黑及葉片黃化病徵，嚴重者或將萎凋死亡。偶而也見維管束呈磚紅色之病變。當植株進入開花期則由下位葉往上位葉逐次形成半側葉片黃化（lateral wilt），終至萎凋死亡。這種半側萎凋（圖一）罹病株之維管束皆呈褐化直達莖頂。在葉腋下方之莖部維管束大都呈不明顯之粉紅色病變（非磚紅色），容易分離得病原菌。從上千個病害標本之根部及莖部分離得 Fsp, Fop, *Pythium ultimum* 及 *Rhizoctonia solani* 等四種病原菌。以前二者爲主要，後二者僅佔極少數。Fsp 及 Fop 之分離率，在冬季豌豆田是 7：1，在夏季豌豆田則爲 4：5。可見農民所謂的“立枯病”即是 Fsp 及 Fop 之複合感染[29]（圖一）。目前使用之豌豆栽培品種，即“台中 11 號”、“台中 9 號”及“在來白花”，感染 Fop 之後，會產生葉片黃化（半側萎凋）（圖一），維管束褐化，終至死亡。然而感染 Fsp 之後，則見根腐、黃化及矮化等病徵，除幼苗期會嚴重發病死亡之外，成株不會死亡。在田間，顯然的 Fop 引起的萎凋病比 Fsp 引起的根腐病重要。

自從 Jones[23]描述 Fsp 引起豌豆根腐病之後，許多學者[17,20,23,26,34]皆同意，根腐病菌不是維管束寄生菌，不會引起維管束褐變的病徵；它引起根部皮層腐爛，嚴重時僅在根部維管束有磚紅色的病變，不在莖部發生。然而 Hildreth[22]使用的 Fsp 菌株會引起莖部維管束褐變，和擬萎凋病菌（Fop race 2）所引起的病徵相似。在台灣，我們很容易從死亡的幼苗病株及少數莖部維管束呈磚紅色的罹病成株的根部，分離得具有短形大孢子之 Fsp（以下稱 Fsp-S），偶而也有從莖部維管束分離得具長形大孢子的 Fsp（以下稱 Fsp-L）。這兩種菌株接種到數種不同來源的豌豆品種上，Fsp-S 只會引起根腐病徵，而 Fsp-L 不但會引起嚴重的根腐，在 28℃以上的定溫箱中，也會引起接種植物之根部及莖部維管束呈磚紅色的病變，和 Fop race 2 引起之擬萎凋病徵不同之處，即是不會引起半側萎凋病徵。這個溫度效應吻合田間的栽植條件，亦即夏季豌豆常逢 28℃以上之日平均溫度。又從美國引入之數個對 Fop race 2 及 Fsp 具抵抗性之 P.I. accessions/cultivars，也對 Fsp-L 呈罹病反應，莖部維管束褐化[29]。這些結果說明台灣的 Fsp-L 菌株並非 Fop race 2，而是屬於在高溫條件下，具有侵害豌豆莖部維管束組織，高毒力（highly virulent）的 Fsp。

在台灣，豌豆的主要栽培品種是“台中 11 號”，但仍有許多不同遺傳背景的品種分佈於各栽培區。不難想像 Fop 將會有多種生理小種存在。從各地分離所得之 Fop，依 Kraft & Haglund[25]的方法，鑑定爲 race 2, 5 以及一個新種[29,41]。這個新種與 race 2 在 PDA 上之培養性狀相似，但對判別品種的抗感病略有不同。最近在美國華盛頓州亦發現類似的菌株[21]。鑑於台灣產之新種與 race 2 之差異，僅是新種會感染“New Season”品種，race 2 則不會；又台灣的栽培品種都對新種呈罹病反應，因此仍將之稱爲 race 2，未另訂新名[41]。在高溫條件下，從“台中 11 號”分離所得的大部是 Fop race 2 的擬萎凋病菌，最爲重要。

Fop 之變異與存活

鐮胞菌在培養基上有各種培養形態，不同種鐮胞菌之野生型在形態上亦有差異[27]。最常見之變異型即所謂的粘膜型（pionnotal type）。Pionnotes 爲 Fries 所創，用來描述鐮胞菌在培養基產生鉅量密集大孢子，外觀呈油脂狀[14]。前人研究粘膜型變異菌株，大都强調是培養基上產生的現象，甚少獲自田間標本[15]。我們自田間土壤或病害標本分離所得之衆多豌豆萎凋病菌，一律爲胞叢型，未有粘膜型者。但將野生型多次單胞分離培養即可變異爲粘膜菌絲型及粘膜型，其變異方向爲：

胞叢型 ⟷ 粘膜菌絲型 ⟶ 粘膜型[6]



Fig 1. Upper left: Garden peas showing root rot and vascular discoloration in field specimens identified as a disease complex in which root rot and wilt act together. Upper right: pea wilt (cultivar TC-11) caused by *Fusarium oxysporum* f. sp. *pisi* race 2 consisting curling and chlorosis in leaves on one side (lateral wilt) of the plant. Lower: Effect of soil amended with calcium cyanamide at the rate of 300 Kg/ha on reducing pea wilt at Hsin-sir experimental plot in 1986.

這種在培養基上產生的變異菌株，到底是否存在於田間？或者它們在田間的行爲如何？幾無資料可循。在文獻上，僅有 Oswald[33] 曾經偶而從罹患根腐病之小麥病組織分離得 *F. roseum* f. sp. *cerealis* 粘膜型菌株。可見變異菌株或許發生於自然界，卻爲其他因素所抑制。後來許多報告[1,7,9,11,14,40,42]指出，這種變異菌株之毒性（ virulence ）比原來的野生型弱，卻鮮有研究其存活能力。有一例子，香瓜蔓割病菌（*F. oxysporum* f. sp. *melonis* ）之變異菌株在消毒土中表現之毒性與野生型菌株相同。但在自然土中則較差，並且無法存活一年以上[30]。於是 Miller[31]提出兩個假說解釋其機構：1. 病原菌之遺傳性質在土壤中比在培養基上穩定；2. 如果變異菌株存在於田間，則存活能力較差。後來 Lin[28]發現 *F. roseum* "Avenaceum" 在培養基上極易由胞叢型變異爲粘膜型。粘膜型菌株在無菌狀況下與野生型菌株有相等的毒性，但在自然土中則無，而且存活不超過 2～3 星期，解釋爲粘膜型菌株無法與土壤微生物競爭的緣故。最近在 *F. moniliforme*[1]及 *F. oxysporum* f. sp. *apii*[9]的研究顯示粘膜型與胞叢型菌株，在土壤中之存活能力無差異，或者粘膜型更能存活。似乎鐮胞菌粘膜型變異菌株之存活能力乃因種類而異。進行這種存活試驗，大都在不算長的時間內，比較叢胞型與粘膜型菌株在土壤中數目變化的差異，往往忽略各種菌類的田間臨界濃度（ threshhold density ）。例如，許多 *F. oxysporum* 在田間的臨界濃度乃介於 10^2～10^3 propagules/g soil[13,18]。假如試驗結束時，供試菌在土壤中之數目雖較原加入者低，卻仍高於臨界濃度時，似乎仍不可判定供試菌在土壤中不能存活或存活不好。因此，我們以 Fop，芹菜黃葉病菌（*F. oxysporum* f. sp. *apii* ），甘藷蔓割病菌（ *F. oxysporum f.* sp. *batatas* ）及西瓜蔓割病菌（ *F. oxysporum* f. sp. *niveum* ）之叢胞型與粘膜型菌株爲材料，在自然土與消毒土中進行接種與存活試驗達 18 個月之久，使供試菌在土壤中之數目下降至無法用培養基偵測爲止。結果發現 Fop 之粘膜型菌株之毒性確實遜於胞叢型菌株，而且無法在土壤中存活。而其他三個供試菌之胞叢型與粘膜型菌株在土壤中皆能存活，在 18 個月內，其數目仍維持在臨界濃度以上[6]。 Bruehl[15]强調，假如粘膜型菌株能從土壤中獲得，也僅是短暫現象，終將在土中消失，如 Fop, *F. oxysporum* f. sp. *melonis* 及 *F. roseum* "Avenaceum" 等菌符合 Bruehl 氏之假說，其他則否，因種類而異。

Fop 在水稻田裡之生態

許多作物與水稻輪作的制度是台灣地區特殊生態環境。由於每期稻作約有 40 天以上的淹水期，淹水處理會造成土壤的嫌氧狀態及產生毒素[13,18]，不利病原菌之存活。例如，輪作水稻一年，使棉花萎凋病菌（ *Verticillium dahliae*[16]及 *F. oxysporum* f. sp. *vasinfectum*[18]在土壤中之密度降低，從而達到控制病害的效果；亦可降低土壤中香蕉黃葉病菌（ *F. oxysporum* f. sp. *cubense* ）的密度，但是當再植感病品種的蕉苗後，病原菌密度又很快地恢復[10,37]。因此，輪作水稻對土傳性病菌之防治效果，似乎因病菌不同而異。然而，一般而言，輪作水稻被認爲可短期防治土傳性病害。事實上，台灣冬季豌豆的栽培方式，是經過兩期水稻輪作的。由田間觀察的資料顯示，萎凋病在冬季豌豆田較夏季豌豆田輕微，但是依然有少數的冬季豌豆田遭受萎凋病的嚴重危害。其接種源來自何處？筆者與同事們[2]曾在溪湖一塊冬季豌豆田進行兩年的試驗，研究 Fop 及 Fsp 在土壤中的生態行爲。 Fop 及 Fsp 在土中之垂直分佈以微生物活動最頻繁的耕犁層（土深 0～25 cm ）密度最高。表土（ 0～10 cm ）之土壤容積密度爲 1.11～1.22 （ g/cm^3 ）。由於水田整地時的操作（ puddling ），使部份土壤粘粒逐漸沉積於 11～15 cm 處（ tillage pan ），土壤容積密度略增至 1.48 g/cm^3，孔隙變小，空氣流動受阻，不利病原菌存活，因此病原密度偏低。而耕犁層下方的土壤被犁具壓擠成硬土層（ pressure pan ）（土深 25～30 cm ），土壤容積密度偏高達 1.57 g/cm^3，阻擋排水，容易造成嫌氧狀態，使病菌數目銳減。在硬土層下方（土深 30～40 cm ）則排水良好[18]，而且微生物活動簡單，病原菌又可存活。這些病原菌受硬土層的束縛，無法爲害耕犁層中之豌

豆的根部。可見與病害最有關係的乃是耕犁層的病原密度，卻深受耕犁與淹水的影響。由於輪作水稻時，土壤經犁具操作，使得 Fop 及 Fsp 在耕犁層的土壤中成爲逢機分佈；淹水處理則使病原菌之密度呈週期性的起伏。經兩期水稻輪作後降至最低，尤其 Fop 的密度會降到無法偵測的程度。使得裡作豌豆不致嚴重被害。當豌豆種植後，土壤中之病原密度又逐漸回升。由於冬季豌豆採不整地的糊籽栽培，壓成磐未被破壞，病原菌極少可能來自壓成磐下方存活的病原菌。我們曾在水稻、稗、雀稗、節花路蓼、小葉灰藋、龍葵及山芥菜等的根部分離得病原菌，但出現頻率不高。然而，爲何有些冬季豌豆田的植株仍遭 Fop 及 Fsp 的嚴重危害？原來市售的豌豆種子攜帶有病原菌，而且未實施藥劑處理，有些樣品可傳播高達 30% 的發病率，會抵銷輪作水稻的防治效果[2]，是以種子保護措施成爲刻不容緩的重要課題。

種子處理藥劑對豌豆萎凋及根腐病之影響

Snyder and Alexander[36]早於 1961 年即指出豌豆攜帶萎凋病菌是新植地的重要感染源。豌豆種子含有豐富的營養，在土壤中發芽時會釋出大量的醣類及氨基酸，容易引起許多棲息於土中之病原微生物的侵襲，造成種子腐爛或嚴重的猝倒病徵[18]。因此，在國外豌豆種子必先經過藥劑處理加以保護，防止病害的發生[21]。鑑於本省豌豆種子攜帶 Fop 及 Fsp 的事實[2]，筆者曾經進行實驗室與田間種子處理藥劑的篩選工作（未發表）。

實驗室及溫室試驗

在 PDA 平板上加入 1000 ppm 或 500 ppm 之蓋普丹（ Captan, 50% W.P.）（ N-trichloromethylthio-4-cyclohexene-1, 2-dicarboximide ），1600 ppm 或 800 ppm 之得恩地（ thiram，80% W.P.）（ Tetramethylthiurm disulfide ），500 ppm 或 250 ppm 之貝替芬（ Bavistin，50% W.P.）（Methyl-2-benzimidazole carbamate ）及 800 ppm 或 400 ppm 之 Phygon（ Dichlone, 40% W.P.）（ 2, 3-dichloro-1, 4-naphthoquinone ）等藥劑，以及不含藥劑之 PDA 爲對照組，然後移植新鮮的 Fop 及 Fsp 菌落圓盤，置 24 或 28℃定溫箱中 7 天。結果上述藥劑皆能抑制 Fop 及 Fsp 的菌絲生長，尤以貝替芬效果最佳。另外，將“台中 11 號”豌豆種子分別浸泡於各含 10^5 spores/ml 之 Fop 或 Fsp 胞子懸浮液中一小時，於室內陰乾。再用上述四種藥劑（ 2.2 g/Kg seed ），添加或不添加粘著劑（ graphite ）行粉衣處理，以不加菌及藥劑之豌豆種子爲對照處理。將處理種子置於 PCNB 培養基[32]上，置 24℃定溫箱中 5 天。發現上述藥劑不影響種子發芽，卻影響病菌之分離率。其抑制效果依序爲蓋普丹、得恩地，及貝替芬，而 phygon 及對照組皆無法抑制病原菌之分離率。在另一溫室試驗，將上述藥劑粉衣豌豆種子，種植於蛭石（ vermiculite ）或含有 Fop 及 Fsp 之病土（ infested soil ）中（病菌密度各爲 10^3 propogules/g soil ），置室溫中（ 18～30℃），經 4 週後觀察並記錄根腐及黃化指數（根腐指數分爲 0～4 級，包括 0＝根部健全，1＝根部有輕微褐斑，2＝根部有大型褐斑，3＝莖基部有褐斑，4＝莖基部呈黑褐色腐爛；黃化指數亦分爲 0～4 級，包括 0＝無黃化葉片，1＝黃化葉片少於株高的 25%，2＝黃化葉片佔株高之 26～50%，3＝黃化葉片佔株高之 51～75%，4＝黃化葉片佔株高之 76～100%）。結果顯示，在蛭石裡，種子拌藥及粘著劑之防治效果優於單獨拌藥之處理，尤以得恩地最好，蓋普丹次之，而貝替芬及 phygon 則與對照組無差異。而經藥劑粉衣之種子，若種植於含有 Fop 及 Fsp（各爲 10^3 propagules/g soil ）之病土中，於 4 週後嚴重發病，7 週後死亡，沒有防治效果。

田間試驗

在溪湖一處無法用培養基從土壤測得 Fop 及 Fsp 之水稻輪作田種植拌菌（ Fsp 及 Fop 之懸浮液各爲 10^5 spores/ml ）及拌藥（ 2.2 g/Kg of seeds 之蓋普丹或得恩地加上等量之粘著劑，graphite ）之種子，在田間做成下列處理：1. 種子拌菌並拌藥；2. 種子只拌藥；3. 種子只拌藥，卻在植穴中加入 100 g 之病土（ 10^3 propagules/g soil ）；4. 種子拌菌，不

拌藥，種植於土壤中（ CK1 ）及 5. 種子不拌菌亦不拌藥，種植於加入病土之植穴中（ CK2 ），採逢機區集設計，三重複。播種 14 天後，各處理皆有少數植株發生猝倒現象，差異不顯著（經檢查乃由一些屬於 Phycomyctes 之 sugar fungi 所引起），而大部份的植株皆生長良好。經 6 週後才開始顯示葉片黃化的病徵，發病率於 9 週後不再增加，但罹病株的黃化指數愈來愈高，終致死亡。前三個處理之根腐植數分別爲 2.8、1.8 及 3.6（得恩地）；2.2、1.6 及 3.6（蓋普丹）；而 CK1 及 CK2 分別爲 2.4 及 4.0。植株萎凋死亡率（ % ）分別爲 16、7 及 62（得恩地）；15、6 及 56（蓋普丹）；而 CK1 及 CK2 則分別爲 15 及 82。在統計上使用藥劑之效果差異不顯著，尤其在植穴中加入病土之處理，使得藥劑處理毫無經濟價值。

土壤添加物對 Fop 及 Fsp 之防治

上述冬季豌豆田因爲經過兩期水稻輪作，而且冬季之溫度較低，日平均溫度會降至 20 ℃以下，適合豌豆生長，萎凋病及根腐病大爲降低。但是夏季豌豆之栽培，卻逢高溫多溼的環境，日平均溫度可達 28℃以上，不適豌豆生長。又適宜豌豆生長的土壤 PH 值爲 6.5[3]，卻有許多夏季豌豆田土壤偏酸性，尤其在山坡地的土壤 pH 值常落在 4.5～5.5 左右。根據前人[13,19,24,35]報告酸性土壤較適宜若干鐮胞萎凋菌之發展。在上述不良的環境條件下，豌豆或因此易失一般抗性（ general resistance ）[18]，易爲病菌所乘，造成萎凋及根腐病猖獗，應設法避免種植豌豆。然而農友爲較高的市場價格，仍競相種植夏季豌豆。保護策略的釐定，或許應該是多方面的綜合防治[39]。我們[5]研究一些土壤添加物對土壤 pH 值之影響及對豌豆萎凋及根腐病之防治效果。

在溫室裡取新社土壤（ pH = 4.2 ），經石灰處理調節其 pH 值於 4.4～7.4 之間，加入病原菌及養份（ glucose 及 asparagine 各 0.25% ）測其發芽率。結果發現 Fop 及 Fsp 之厚膜孢子在 pH 4.5～5.5 之間的發芽率最高，分別達 49% 及 30%。從 pH 6.5 以上，其發芽率開始降低，在 pH 7～8 之間，發芽率分別爲 26% 及 10% 左右。但是接種試驗顯示，pH 4.0～7.0 對萎凋及根腐病之發病程度並無影響，pH 7.4 的處理雖然會減少該二病害的發生，其萎凋及根腐指數卻仍分別達 64.3% 及 2.0，未達經濟防治效果。另外，在 1985（ 3～5 月）及 1986 年（ 3～5 月），於新社試驗田的土壤（ pH 4.0 ）中施用氰氮化鈣（ 300 Kg/ha ）（ Perlka SKW Trostberg 產品，含 N, 18%；CaO,50% 以上），苦土石灰（ 1800 Kg/ha ）（輕質碳酸鈣，瑞元化工廠）及自製的 SH 混合物（ 1600 Kg/ha ）（蔗渣，4.4%、稻殼，8.4%、蚵殼粉，4.25%、尿素，8.25%、磷酸氫鈣，13.16%、硝酸鉀，1.01% 及矽酸爐渣，60.5% ）[38]等土壤添加物，及不加任何處理爲對照，採逢機區集設計，三重複。土壤經添加物處理後，隨即灌水，兩週後開畦點播經藥劑（得恩地及粘著劑 graphite ）處理之豌豆種子。結果發現各種處理皆提升土壤 pH 值 1～2 個單位，直到 63 天後維持在 pH 5.0 左右；田間植株於 7 週後開始表現黃化病徵，經檢查是 Fop 引起的病害。以氰氮化鈣及 SH 混合物之處理的發病速度較慢，到第 11 週，氰氮化鈣，SH 混合物，石灰，及對照等處理之發病率在 1985 年期分別爲 11%、49%、56% 及 80%，而 1986 年期則分別爲 39%、46%、57% 及 76%，氰氮化鈣的防治效果最優越（圖一），而 SH 混合物只是遲緩萎凋病的發病速度，是量而不是質的防治效果。以間歇性採收豆莢而言，遲緩發病雖可保護部份產量，但仍未達經濟防治。

結　語

植物病害防治是一種藝術，一個病害的發生與防治絕對不是單因子所造成的。因此釐定一個病害的保護策略，應是多方面的試驗研究，發展綜合防治方法才能達到經濟效益的目標。以豌豆萎凋病而言，在田間常與根腐病造成複合感染，又冬季豌豆與夏季豌豆的栽培環境截然不同，環境的壓力互異非常複雜。綜合上述的試驗研究，在無法取得抗病品種之前，我們推薦選取清潔種子施用種子保護藥劑（一份蓋普丹或得恩地加上一份粘著劑（ graphite ）

（2.2 g/Kg種子），在經過兩期水稻輪作田種植冬季豌豆。不鼓勵種植夏季豌豆，雖然試驗結果顯示氰氮化鈣可保護夏季豌豆，卻仍是火中取粟，冒險的很。

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ABSTRACT

Lin, Y. S. 1991. **The occurrence of pea wilt and its control in Taiwan.** Plant Prot. Bull. 33:36-44. (Departement of Plane Pathology, National Chung Hsing University,

Taichung, Taiwan, R.O.C.)

In Taiwan, most garden peas were cultivated normally from November to February in the rice-rice-peas rotation fileds (winter peas) and also, planted either from late August to December or from February to May in many dryland fields at different elevations all over the island (summer peas). Pea seedlings in both seasons were suffered with a root rot caused by *Fusarium solani* f. sp. *pisi* (Fsp) showing the symptoms of root rot, leaf yellowing and occassionally, a red vascular discoloration. The diseased plants were usually not dead. When the pea plants grew up to the flowering stage, they would be damaged by a wilt caused by *F. oxysporum* f. sp. *pisi* (Fop) with leaf yellowing on one side (lateral wilt), vascular discoloration and wilt symptoms. The pea wilt was the most important disease of peas, especially, severe in summer peas. The isolates of Fop were identified as races 2 and 5. Fop race 2 was more frequently isolated from the major commercial cultivar, TC-11. The cultural variant, a pionnotal type of Fop race 2 was easily obtained from the PDA culture of wild type (sporodochial type). The wild type isolates were highly pathogenic to peas and survived well in soils, while the variants were less pathogenic and survived poor in soil. In a winter peas field, Fop race 2 was found mostly in the soil of tillage layer and was able to be reduced to the non-detectable level after rotating with two crops of paddy rice and hence, the pea wilt was reduced. However, the field was colonized with the pathogen after growing a crop of peas. The inoculum probably came from the infested seeds, weeds and soil particles. Seed treatment with thiram plus graphite (2 g/Kg seed) could protect the winter peas at early stage, but not for the summer peas. Using calcium cyanamide at the rate of 300 Kg/ha as soil amendment could reduce the pea wilt of summer peas.

(Key words: Fusarium wilt and root rot of peas, physiological race, cultural variant, survival, seedborne, soil amendment, integrated control.)

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Control of Sclerotinia Rot of Sunflower and Chrysanthemum

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ABSTRACT

WU, W. S. 1991. **Control of sclerotinia rot of sunflower and chrysanthemum.** Plant Prot. Bull. 33:45-55.

Benomyl and DCNA were able to inhibit the growth of *Sclerotinia sclerotiorum* in cultural medium and able to control sclerotinia rot of sunflower in field. Vinclozolin expressed better effectiveness of disease control on sunflower than DCNA and iprodione. Vinclozolin inhibited the germination of ascospore completely and caused the ascospore losing its cytoplasm. When soil treated with calcium cyanamide, the survival of sclerotia declined and the disease on chrysanthemum was reduced significantly due to the amount of apothecium was reduced. *Trichoderma viride* isolated from decayed sclerotium was able to infect *S. sclerotiorum* and produced some inhibitory substance(s) to inhibit the growth of the studied pathogen. Spraying the spore suspension of *T. viride* onto sunflower was able to reduce the disease rate significantly, but was unable to increase the yield of sunflower. Soil solarization by mulching the field soil with black polyethylene sheet was an effective method to reduce the amount of apothecium significantly. Consequently, the percent of disease was significantly reduced in 1986 but not in 1987. The temperature on the top soil at solar energy-treated field was 10℃ higher than untreated soil, but 5℃ higher when the soil temperature was measured at the depth of 5 cm from the soil surface. Sclerotia lost their vitality when the soil was wet and the soil temperature was raised to 45℃ for four hours a day for four days.

(Key words: *Sclerotinia sclerotiorum,* chemical control, biocontrol, integrated control)

INTRODUCTION

Sclerotinia sclerotiorum (Lib.) de Bary is an important plant pathogen due to the fact that it has a wide spectrum of host ranges and ability of survival for long time. This pathogen was able to infect about 400 different species of plant in 72 families[1,3,19,30,31,33,40].

Generally, *S. sclerotiorum* produced black, irregular-shaped slerotia under various stress conditions. Sclerotium is the fundamental structure of this pathogen to survive for several years under natural field conditions[4,10,34]. Although sclerotium of this pathogen can be the primary inoculum[6,14,39], ascospore, usually, plays much more important role as primary inoculum to cause plant to be infected. Ascospore was produced in apothecium which was initiated from sclerotium. Each apothecium contained approximately 1.3-2.3 $\times 10^6$ ascospores[34,41]. The duration of each apothecium to release ascospore can last for 11-12 days, once the apothecium started to discharge ascospore[41]. Since ascospores were produced only once from one specific sclerotium and infected host plant once in one growing season, the disease caused by *S. sclerotiorum* should be regarded as monocyclic or simple interest disease[38].

S. sclerotiorum is world-wide spread and existed in Taiwan, especially in notrhern Taiwan. This pathogen caused evidently losses on vegetables and flower plants when the temperature was below 25℃ and weather was wet in Taiwan. In order to reduce the incidence of this pathogen, chemical control was the most popular practice. However, the adverse effect of applying chemical was mentioned frequently[7,11]. For minimizing the drawbacks of using chemicals, the most promised chemical should be screened. Besides, other control measurements should be considered solely or applied integratly with less amount of fungicides. Biological control has endurable effect to inhibit pathogens without polluting or disturbing the environment dramatically[7]. Since 1976, solar energy has been applied to control soil-borne pathogens[18], solarization has been identified as an effective measurement to improve plant growth, increase yield and reduce the amount and severity of disease[12,13,28,29,35,37]. The main purpose of this study is try to find out some effective and available methods to control this pathogen in Taiwan.

MATERIALS AND METHODS

Tested plants

Sunflower and chrysanthemum were used in this study. Sunflower seeds and chrysanthemum seedling were sown and transplanted, respectively, in field when bioassay was needed.

Chemical control

1. laboratory experiment

Benomyl (methyl 1-(butylcarbamoyl)-2-benzimidazole carbamate, Benlate 50%, du Pont), DCNA (2, 6-dichloro-4-nitroaniline, Dicloran 50%, The Boot's Co.), PCNB (pentachloronitrobenzene, Terraclor 75%, Olin) and zineb (zinc ethylene bisdithiocarbamate, Zineb 75%, Luxan) were prepared in potato dextrose agar (PDA) and broth (PDB) at either 250, 500 or 1000 ppm (active ingredients, a.i.). The same size and age of inoculum was transferred either on the center of PDA plate or in PDB. All the cultures were incubated at 25℃ for certain period of times. Each treatment consisted of four replicates and repeated twice.

Compared to DCNA, iprodione (3-(3, 5-dichlorophenyl)-N-isopropyl-2, 4-dioxoimidazolidine-1-carboximide, Rovral 50%; Rhone-Pouienc Inc.) and vinclozolin (3-(3, 5-dichlorophenyl)-5-methyl-5-vinyl-1, 3-oxazoladine-2, 4-dione, Ronilan 50%, BASF) were also prepared at either 0.01, 0.1, 1, 10, 100 or 1000 ppm (a.i.) in PDA. When the ED_{50} was less than 1 ppm, further tests were made at concentrations of 0.05, 0.1, 0.5, 1, 5 and 10 ppm. The mycelial growth was measured after incubating this pathogen under 22℃ for

certain period of time.

DCNA and vinclozolin (1000 ppm, a.i.) were sprayed onto sunflower 5, 2 or 0 days before and after inoculation of ascospores. After inoculation for two days, the inoculated tissues were treated and observed under scanning electron microscope (Hitachi S-550).

Either 0.5, 0.25 or 0.05 g of calcium cyanamide (SKW Trostbery) was mixed with 100 ml of field soil (40% moisture content). Ten sclerotia were immersed in the soil and incubated in 40℃ for 4 hr and in 30℃ for the rest of 20 hr. everyday. After incubating for either 2, 4, 8 or 12 days, the survivability of sclerotia was determined. Each treatment consisted of three replicates.

2. field experiments

Sunflower was planted in 0.05 ha. field which was divided into four blocks. Each treatment consisted of four replicates. Each replicate consisted of either 40 or 50 sunflower or 200 chrysanthemums. Randomized completely block design was used in this study. The field soil was clay loam.

For the first field experiment, each treatment consisted of 40 plants which were planted in adjacent two rows. Every row was 25 cm apart from each other. Each row was 600 cm long. Benomyl, DCNA, PCNB, and zineb were sprayed at the concentration of 5.25 g (a.i.)/6 l when sunflower had grown for one month. Afterwards spraying was once every week. In the second field experiment, DCNA, vinclozolin, mancozeb, PCNB were used. Each chemical consisted of two treatments. One was applying 50 g (a.i.) of chemical along the seeding sites plus spraying with the same chemical 14 days after planting. The other was spraying only which was started 14 days after planting. The concentration of each sprayed chemical was 1000 ppm (a.i.). DCNA, iprodione and vinclozolin were used in the third field trial. After 30 days of planting, 1500 ppm (a.i.) of each chemical was sprayed and continued to be sprayed for eight times at 7-day interval.

Chrysanthemum was planted in the *S. sclerotiorum*-infested field for determing the effective of soil treatment with different chemicals. The size of each block was 2.2 × 3.9 M^2. Two hundred chrysanthemum seedlings were planted in each blocks. 250 g of either urea or calcium cyanamide and 1000 ppm vinclozolin were treated with and sprayed on, respectively, the field. The disease rate and survival of sclerotia were recorded and analysed by Duncan's multiple range test.

Biological control

1. isolation of antagonists

The sclerotia of *S. sclerotiorum* were buried in field at the depth of 5-10 cm. After 30 days, microflora on the sclerotia were isolated by dilution plate on PDA. Soil microflora were also isolated by dilution method on sclerotia-powder medium. The sclerotia-powder medium consisted of 2 g powder of sclerotia, 8 g agar and 400 ml dist. water.

2. screening the antagonists

Capability of either hyperparasitism, antibiotic activity or competition[22] were used as the criterion to determine which isolated soil microorganisms were good for further study.

3. field experiment

The spore suspensions of *Trichoderma viride* 8I, *T. viride* 8IR, *Gliocladium virens* and *Bacillus* sp. were prepared in glycerol-sodium nitrate nutrient solution[22]. Spraying began 30 days after planting sunflower and continued to spray for eight times at 7-day interval. All treatments in the field experiment had four replicates and followed by randomized

completely block design.

Physical control

1. soil solarization

Black polyethylene sheet (0.2 mm in thickness) was covered on field plots for 50 days (Sept. 5-Oct. 25, 1986) in the first experiment, and for 35 days (Aug. 29-Oct 2, 1987) in the second experiment. Afterwards, 200 chrysanthemum seedlings was transplanted to each of these treated plots. Control was seedling growing in the untreated plots.

2. determining the effect of temperature on the survival of *S. sclerotiorum*

Every 10 sclerotia (0.4-0.6 cm in diam.) were buried in field soil which was filled in 100 ml beaker. Those beakers were separately incubated under 45, 40, 35 and 30℃ for 1, 2, 4, 8 and 14 days. When these beakers were incubated under 45, 40 and 35℃ , the incubation time was 4 hr a day and they were transferred to 30℃ for the rest of 20 hr everyday. Survivability was determined by counting whether those scleotia was able to germinate on PDA.

Every 10 sclerotia was also buried at the depth of 5 cm in each field plot which was treated with solarization. After 50 days, sclerotia were removed from field and cleaned with running tap water. Then the survivability of sclerotia was also determined as aforementioned.

RESULTS

Chemical control

1. laboratory experiment

Benomyl and DCNA stopped the growth of *S. sclerotiorum* after three days of incubation, this inhibitory effects remained even till 14 days after incubation (Table 1). PCNB and zineb slowed down the growth rate of *S. sclerotiorum* on PDA. Besides, PCNB at all tested concentration altered the mycelial color from white to brown. Small sclerotia were formed on PDA containing either 250 of 500 ppm zineb, but irregular colonies were formed when the concentration of zineb was 1000 ppm.

This studied pathogen was unable to grow in PDB which contained 1000 ppm benomyl (Table 1). All the other chemicals reduced significantly the dry weight of *S. sclerotiorum* compared to control. *S. sclerotiorum* was unable to grow in PDB which contained 1000 ppm of DCNA in the first two weeks, but started to form a dense layer of mycelia and irregular sclerotia after three weeks of

Table 1. The effects of four different fungicides on the growth of *Sclerotinia sclerotiorum*

parameter	concentr. (ppm)	diam. of colonies (cm)[1]				
		benomyl	DCNA	PCNB	zineb	CK
diameter of colonies[3]	250	nil	nil	2.8 a[2]	3.4 a	8.4 b
	500	nil	nil	3.0 a	3.4 a	8.4 b
	1000	nil	nil	3.0 a	2.8 a	8.4 b
dry wt. (g.)[4]	1000	0 d	0.46 b	0.16 cd	0.26 bc	0.69 a

1) Each treatment consisted of four replicates and was repeated twice.

2) Data, the average of every treatment, followed by common letter in the same row did not differ significantly ($p = 0.05$) by the Duncan's new multiple range test.

3) Data were obtained after three days of incubation under 25℃ .

4) Data were obtained after 21 days of incubation under 25℃ .

incubation.

Compared to DCNA and iprodione, vinclozolin was the most effective in inhibiting the mycelial growth of *S. sclerotiorum* on PDA. The concentration of ED_{50} of vinclozolin, iprodione, DCNA to inhibit the growth of *S. sclerotiorum* was 0.25, 0.27 and 1.47 ppm (a.i.), respectively. The concentration of ED_{90} of vinclozolin, iprodione, and DCNA to inhibit the growth of *S. sclerotiorum* was 1.24, 1.37 and 7.37 ppm, respectively.

2. field experiment

Benomyl, DCNA and PCNB were able to reduce the percent of disease when sunflower grew for 70 days, but were unable to continue to control this disease when sunflower was ready for harvest (Table 2). Among the four fungicides, DCNA was the most effective fungicide to control *S. sclerotiorum* in field.

Among DCNA, vinclozolin, mancozeb and PCNB, DCNA and vinclozolin were able to reduce disease rate and increase the percentage of surival of sunflower significantly (Table 3). However, only vinclozolin provided the capability to increase the yield significantly than the other three chemicals. There was no significant difference between two methods of applying either chemical.

DCNA, iprodione and vinclozolin were able to control sclerotinia rot of sunflower (Table 4). Besides, DCNA and vinclozolin were able to increase yield, but not for iprodione.

Ascospores germinated readily on the untreated sunflower, but failed to germinate on vinclozolin-treated sunflower after ten days of inoculation. Although DCNA allowed some ascospores to germinate, the germination was limited. Besides inhibiting the germination of ascospore, DCNA, iprodione and vinclozolin were able to cause the affected ascospore to leak their cytoplasm.

Chrysanthemum sclerotinia rot was significantly reduced when the field soil was sprayed with vinclozolin or mixed with calcium cyanamide (Table 5). Besides, calcium cyanamide reduced the survivability of sclerotia of *S. sclerotiorum* significantly in field soil. Chrysanthemum grew significantly higher than other treatments when field soil was mixed with urea.

Biological control

One hundred and eleven isolates of microorganism were isolated from sclerotia which were incubated in field soil for 30 days. Among them, *Trichoderma viride* 8I and 8IR, as well as *Gliocladium virens* were identified as hyperparasites of *S. sclerotiorum*. They produced short hyphal branches which attached to the susceptible host hyphae and caused them to be evacuated or disintegrated.

Table 2. The effects of four different fungicides on controlling sclerotinia rot of sunflower

days after planting[1)]	percent of disease[2)]				
	benomyl	DCNA	PCNB	zineb	CK
70	10.6[3)]	9.8	12.5	22.5	20.6
120	51.3	46.1	58.3	57.7	55.2

1) Spraying chemical (5.25 g/6 l, a.i.) was once a week after 30 days of planting.

2) Percent of disease = disease rating × no. of plant of the same category of disease rating/5 × 160 (total tested plants).

3) Data were the average of four replicates.

Table 3. The effects of four different fungicides on controlling sclerotinia rot of sunflower

parameter	DCNA		mancozeb		PCNB		vinclozolin		CK
	I[1]	II[1]	I	II	I	II	I	II	
disease rate[2]	2.16 b[3]	2.50 b	3.50 a	3.75 a	3.75 a	3.28 a	0.75 c	1.19 c	3.66 a
% survival	21.00 b	19.25 b	4.75 c	3.00 c	4.75 c	7.25 c	32.50 a	32.75 a	7.5 c
yield (kg)	220.13 b	176.9 b	91.25 b	110.6 b	130.0 b	163.1 b	546.3 a	576.3 a	163.8 b

1) I: soil incorporated and plant sprayed with a specific tested fungicide;
II: spray tested fungicides only.

2) O: healthy, 1: leaves infected only, ——, 4: wilting.

3) Data, average of four replicates and recorded at harvest time, followed by the same letter in the same row were not significantly ($p = 0.05$) different.

Table 4. The effects of three fungicides on controlling sclerotinia rot of sunflower

parameter	treatment[1]			
	DCNA	inprodione	vinclozolin	CK
disease rate after 79 days of planting	8.3 bc[2]	8.8 bc	3.8 c	22.4 a
disease rate after 92 days of planting	38.9 b	39.6 b	27.1 c	60.4 a
average yield (kg.)	10.7 ab	5.7 c	13.7 a	3.8 c

1) Each treatment consisted of four replicates. Each replicate had 50 tested plants. The concentration of all tested fungicides was 1500 ppm (a.i.)

2) Data, average of four replicates, followed by the same letter in the same row differed significantly ($p = 0.05$) by Duncan's multiple range test.

Table 5. The effects of different soil treatment on controlling sclerotinia rot of chrysanthemum

parameter	treatment[1]			
	vinclozolin	urea	calcium cyanamide	CK
percent of disease	3.36 b[2]	7.26 ab	3.30 b	12.88 a
height of plant (cm)	39.39 bc	49.70 a	46.71 ab	39.96 bc
% survival of sclerotia	—	100.00 a	10.00 b	100.00 a

1) Each treatment consisted of four replicates. Each replicate had 200 seedlings. 250 g of urea and calcium cyanamide was mixed thoroughly with soil of each block ($2.2 \times 3.9 m^2$). 1000 ppm vinclozolin was sprayed on the soil before planting.

2) Data, average of four replicates, followed by the same letter in the same row differed significantly by Duncan's multiple range test.

G. virens was able to penetrate into and grew within the hyphae of *S. sclerotiorum*. *T. viride* produced appressorium-like structure to press against the hyphae of *S. sclerotiorum*. Besides, they produced some inhibitory metabolites which caused swelling and plasmolysis of affected cells of *S. sclerotiorum*. The growth of *S. sclerotiorum* was inhibited eventually.

T. viride 8IR, the DCNA-tolerant strain, had the same capability to reduce the disease rate significantly as *T. viride* 8I (Table 6), but was unable to increase the yield of sunflower significantly. *G. virens* and *Bacillus* sp. were also able to reduce some degree of disease rate.

Physical control

Solarization was able to reduce the amount of apothecium as effective as soil treated with calcium cyanamide (Table 7). Spraying vinclozolin and soil treated with calcium cyanamide reduced disease rate significantly in 1986 and 1987, but solarization reduced disease rate significantly only in 1986 and not in 1987. Spraying vinclozolin was not able to reduce the amount of aprothecium significantly in field.

The temperature of solarization-treated top field soil can be reached to 45-50℃ and

Table 6. The effects of different antagonists on controlling sclerotinia rot of sunflower

parameter	treatment[1]				
	T. viride 8I	*T. viride* 8IR	*G. virens*	*Bacillus* sp.	CK
disease rate after 79 days of planting	11.4 b[2]	10.5 b	13.3 ab	13.9 ab	22.4 a
disease rate after 92 days of planting	46.8 b	45.8 b	48.9 ab	51.9 ab	60.4 a
yield (kg)	4.8	4.3	3.9	3.3	3.8

1) Each treatment consisted of four replicates. Each replicate had 50 tested plants.
2) Data, average of four replicates, followed by the same letter in the asme row differed significantly ($p = 0.05$) by Duncan's multiple range test.

Table 7. The effects of solarization on controlling of sclerotinia rot of chrysanthemum compared to spraying vinclozolin and soil treated with calcium cyanamide

treatment	no. of apothecium		% disease	
	1986	1987	1986	1987
solarization[1]	2.00 b[3]	4.50 b	2.61 b	46.57 a
vinclozolin[2]	22.00 a	20.75 a	3.36 b	24.55 b
calcium cyanamide[2]	1.50 b	5.75 b	3.30 b	24.87 b
CK	22.00 a	20.75 a	12.88 a	56.25 a

1) Black polyethylene sheet was covered on wetted field for 50 days in 1986 and 35 days in 1987.
2) The method of application was the same as in Table 5.
3) Data, average of four replicates, followed by the same letter in the same column did not differ significantly ($p = 0.05$) by Duncan's multiple range test.

the untreated field soil was 35-40℃ . The temperature at the depth of 5 cm in solarization-treated soil and untreated aoil was 35-40 ℃ and 30-35℃, respectively.

The survivability of sclerotia was reduced to 26.67% when sclerotia were buried in wet field soil (40% water content) and incubated under 45℃ for 4 hr only. Sclerotia incubated in the same type of soil at other temperatures remained 100% alive. After incubation for four days under 45℃ , sclerotia were dead completely. The survivability of sclerotia which were kept under 40, 35 and 30℃ for 14 days was 96.67%, 46.67% and 70%, respectively. The survivability of sclerotia was reduced to 50% when they were buried in solarization-treated soil in field after 35 days of treatment.

DISCUSSIONS

Although benomyl was found to be able to control white rot of cucumber[8] and sclerotinia blight of peanuts[27] effectively, benomyl failed to control sclerotinia rot of sunflower in the first field trial regardless of the fact that benomyl was able to inhibit this studied pathogen to grow in cultural medium within 21 days of incubation. This was probably due to the timing of first spray was late, high inoculum potential and suitable environment for disease development were existed in the field. DCNA reduced the amount of disease of sunflower the most compared to benomyl, PCNB and zineb in this study. DCNA was regarded better than benomyl and PCNB to control lettuce drop[23]. However, vinclozolin provided the best effectiveness to control sclerotinia rot of sunflower than DCNA and iprodione in this study. 5 ppm of vinclozolin was able to reduce the production of sclerotia and controlled lettuce drop very effectively[24]. Ascospore of this studied pathogen failed to germinate on vinclozolin-treated sunflower. Besides, vinclozolin caused the ascospore to lose its cytoplasm. This may be due to vinclozolin was able to inhibit the bio-synthesis of triglyceride and cell wall[26].

Urea was reported to be able to reduce the inoculum density of *Pythium ultimum, Thielaviopsis basicola* and *Macrophomina phaseolina* by producing ammonia in soil[9]. Sclerotinia rot of chrysanthemum was not reduced when soil treated with urea in this study. This was probably due to the amount of urea used to treat the field soil was low and there was no coverage to stop the ammonia to release to the air from soil. Calcium cyanamide was hydrolyzed and released cyanamide in soil. The production of cyanamide was regarded as the major factor of calcium cyanamide which can be used as a soil fungicide to inhibit soil microorganism[15]. Calcium cyanamide was proven to be able to control sclerotinia rot of chrysanthemum effectively in this study. This chemical reduced the production of apothecium from sclerotium of *S. sclerotiorum,* especially significantly when the soil was wet with high temperature. Consequently, the disease was reduced significantly in this study.

Coniothyrium minitans[16], *Gliocladium virens*[36] and *Sporidesmium sclerotivorum*[5] could penetrate in and destroy the sclerotia of *S. sclerotiorum* and reduced the diseases of sunflower and lettuce, etc. *T. viride* was able to control sclerotinia rot of sunflower when spore suspension of *T. viride* was sprayed in this study. This was due to the capability of *T. viride* to infect the hyphae and sclerotia directly and to produce some inhibitory metabolite(s) to inhibit the growth of *S. sclerotiorum.* Besides *T. viride*, the other species of *Trichoderma,* e.g. *T. koningli, T. harzianum,*

had the capability to destroy all the sclerotia in field within 60 days[32]. *T. viride* and *T. polysporum* were proven to be able to produce trichodermin to inhibit the growth and production of apothecium of *S. sclerotiorum*[25]. Whether the inhibitory substance produced by *T. viride* in this study was trichodermin had not been investigated yet.

Soil-borne *Verticillium dahliae* and *Fusarium oxysporum* f. sp. *lycopersici* were reduced significantly by soil solarization[17]. Transparent thin polyethylene sheet had better effect to raise the soil temperature than black polyethylene sheet[17]. Usmani and Ghaffar [37] regarded that there was no different effect on raising soil temperature by either black or transparent polyethylene sheet when the soil was wet. Black polyethylene sheet was used for soil solarization in this study and was efficiently to reduce the amount of apothecium in the field. This treatment was able to raise the soil temperature to 45-50℃. Sclerotia of this studied pathogen were killed when they were incubated under 45℃ four hours a day for four days. This treatment reduced the initial inoculum significantly. Consequently, the disease on chrysanthemum was reduced in 1986, but not in 1987. This inconsistent result was probably due to that this treatment can not impede the arriving of inoculum (air-borne ascospore) from surroundings or other sources.

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摘　要

吳文希 1991 **向日葵及菊花菌核病的防治**　植保會刊 33:45～55。（台北市國立台灣大學植物病蟲害學系）

Benomyl及DCNA在培養基中可以抑制菌核病菌的生長，同時也可在田間防治向日葵的菌核病；但vinclozolin防治向日葵菌核病的效果比DCNA及iprodione還好，vinclozolin在低濃度下即可完全抑制菌核病菌子囊孢子的發芽，並導致子囊孢子的細胞質流失。當土壤以烏肥處理，存活在土壤中的菌核會因而降低其活性，於是菊花菌核病相隨的就因子囊盤數量的減少而減少。由分解的菌核上所分離到的 *Trichoderma viride*，可以感染菌核病菌，並可以所產生的抑制性物質抑制菌核病菌之生長；將 *T. viride* 的分生孢子噴灑在向日葵上，可以顯著地降低病害嚴重度，但是卻未明顯地增產。利用黑色塑膠布覆蓋土面的太陽能處理，可以顯著地降低子囊盤的數目；因太陽能處理的土面溫度比未處理者高10℃，而土面下5公分處的溫度，處理者也比未處理者高5℃；菌核在潮濕的土壤時，當溫度每天有4小時高達45℃時，連續4天，於是就會喪失活力；所以種在以太陽能處理過之土壤中的菊花，其罹患菌核病的數量顯著地降低。

（關鍵字：菌核病菌、化學防治、生物防治、綜合防治）

土壤病原生態與防治研討會專刊 56~62, 1991

Effect of Antibiotic Antagonists on Control of Basal Stem Rot of Chrysanthemum Caused by *Rhizoctonia solani*

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ABSTRACT

Tschen, J. S.-M. 1991. **Effect of antibiotic antagonists on control of basal stem rot of chrysanthemum caused by *Rhizoctonia solani*.** Plant Prot. Bull. 33:56-62.

The antagonists *Aspergillus, Gliocladium, Paecilomyces, Trichoderma* and *Bacillus* spp. were used for the control of basal stem rot of chrysanthemum caused by *Rhizoctonia solani*. All the antagonists protected chrysanthemums from infection by *R. solani*. Solid media for the culture of the antagonists were more useful than culture broths for application as soil additives or as coating materials. When chrysanthemum cuttings were treated with culture extracts of the antagonists, basal rot disease was also inhibited. The degree of the control of *Rhizoctonia* disease in chrysanthemums differed according to the species of antagonists used and the application method.

(Key words: biological control, chrysanthemum basal stem rot, antagonist, *Rhizoctonia solani, Aspergillus, Gliocladium, Paecilomyces, Trichoderma, Bacillus*)

INTRODUCTION

The basal stem rot disease of chrysanthemum caused by *Rhizoctonia solani* is an important soilborne disease in Taiwan. Its incidence during the seedling stage is high and damping-off occurs. As with other *Rhizoctonia* diseases, fungicides have been used to control this disease in Taiwan[10]. In recent years, the use of antagonistic microorganisms to control soilborne plant diseases has also been discussed[2,4]. The control of *Rhizoctonia* diseases on seedlings of rice, mungbean and potato by antagonist, *Bacillus subtilis* F29-3, which produces fengy(my)cin, was first demonstrated by members of our laboratory[5,7,9].

Recently antibiotic-producing antagonists against *R. solani*, including species of the genera *Aspergillus, Gliocladium, Paecilomyces, Penicillium, Trichoderma* and *Bacillus*, have been isolated from Taiwanese soils and their antagonistic actions to *R. solani* studied [8,12]. We present here results on the control of

basal stem rot in chrysanthemums by antagonists which have been grown in different culture media and applied with different methods.

Infection of Chrysanthemums by *R. solani*

R. solani anastomosis group 4 (AG-4) was isolated from chrysanthemums showing basal stem rot symptom. The fungus grew rapidly on yeast extract agar and produced mycelia in abundance. The fungus grew to maturity in a 8 cm-diameter petri dish four days after inoculation. Its pathogenicity was also established when chrysanthemum cuttings were planted in plastic pots (20 × 8 cm) containing soils with a soil-potato inoculum in the middle of each pot. The cuttings began to rot from their basal parts after on week. Disease incidence increased in proportion to the weight of inoculum (Table 1).

Antibiotic Activities of Antagonists of *R. solani*

Antagonists were grown in liquid media to obtain their antibiotic metabolites. The substances produced by the nine antagonists were tested on diffusion agar plates against different indicator microorganisms, *B. subtilis, Saccharomyces cerevisiae, Paecilomyces marquandii* and *Rhizomucor miehei.* Results indicated that all antagonists produced antibiotics and that most of the antagonists inhibited growth of the test fungi (Table 2). The antibiotic activities were related to the growth media used to culture the antagonists and the sensitivity of the test microorganisms. Because antibiotic inhibition of *B. subtilis* and *P. variotii* by metabolites of the antagonists were clearly visible, the two microorganisms were considered to be suitable as test microoranisms for checking the production of antibiotics by the antagonists.

Control of *R. solani* by Coating Chrysanthemum Stems with Antagonists

When the basal portions of chrysanthemum stems were coated with antagonists and the cuttings planted in sands infested with *R. solani*, basal stem rot was inhibited (Table 3). Infection of *R. solani* was reduced by application with different antagonists. The disease incidence was reduced 30% by *B. Subtilis* F29-3 and 78% by *P. marquandii* CF407 relative to the control (100%). The control efficacies by *P. marquandii* (CF407) and *Gliocladium deliquescens* (F-92) were greater than that of *B. subtilis* and was statistically significant. Both fungi are known as hyperparasites of *R. solani*[8,12]. The control effects of mycoparasites appear to be associated with the in-

Table 1. Effect of amount of *R. solani* inoculum on the incidence of basal stem rot in chrysanthemums

Inoculum of *R. solani*[1)] (g/pot)	Disease incidence (%)
1.5	66.7
1.0	41.7
0.5	16.7
Control	0.0

1) The inoculum was prepared in soil-potato medium.

Table 2. Antibiotic activities of antagonists of *R. solani* tested on several microorganisms

Antagonist	Test microoranism			
	Bacill. subtilis	*Saccharom. cerevisiae*	*Paecilom. variotii*	*Rhizom. miehei*
Penicillium sp. CF111	+[1)]	+	+	+
Paecilomyces marquandii CF302	+	+	+	+
Paecilomyces marquandii CF407	+	+	+	+
Gliocladium deliquescens F-92	+	+	+	+
Trichoderma harzianum TVCN1	+	+	−	+
Trichoderma harzianum TVCN2	+	−	−	−
Trichoderma koningii T12	+	+	+	+
Bacillus cereus CB22	−	+	+	+
Bacillus subtilis F29-3	+	+	+	+

1) + : positive; − : no reaction tested with >100 mg/ml crude antibiotic.

Table 3. Control of *R. solani* by coating chrysanthemum stems with antagonists

Antagonist	Disease incidence (%)
Penicillium sp. CF111	46.3 a*
Paecilomyces marquandii CF302	46.3 a
Paecilomyces marquandii CF407	15.6 b
Gliocladium deliquescens F-92	18.8 b
Bacillus sp. CB9	51.9 a
Bacillus sp. CB20	48.1 a
Bacillus cereus CB22	43.8 a
Bacillus subtilis F29-3	48.1 a
Control	68.8 a

* Values not followed by the same letter are significantly different at 5% level (according to Duncan's multiple range test, DMRT).

hibitory activities of their antibiotic metabolites.

Control of *R. solani* by Sawdust Compost Containing Antagonists

In Taiwan, sawdust has been used for cultivation of mushrooms, after which the sawdust waste is used as compost for gardening. We used sawdust compost to cultivate antagonists and samples of it were used as the antagonist inocula that were added in sand beds to study the control of *R. solani*. By experiment 0.5 to 4% of antagonist inoculum was used. The results indicated that any of these concentrations of the inoculum controlled basal stem rot in chrysanthemum and that the degree of control increased in proportion to the amount of antagonist used. Of the 16 antagonists investigated, TVCN1, TVCN2, CF302, CF111 and F29-3 provided the highest control effects followed by T12 and CB22 (Table 4). Generally speaking, 1

% of antagonist inoculum was useful; a higher amount of inoculum not only wasted more antagonists but was also toxic to plants. The phytotoxic phenomenon was observed in applications with CF111, F-92 and F29-3. Because sawdust compost is rich in nutrients, a high concentration of sawdust may promote the growth of *R. solani* and increase the incidence of disease in the no antagonist control.

Control of *R. solani* by Various Organic Substances Containing Antagonists

Three different delivery systems were used for application of antagonists to control of *R. solani*. Sawdusts, rice husks and sawdust composts were inoculated with different antagonists; the control effects by these three preparations on basal stem rot are shown in Figure 1. The results indicated that fresh sawdust is not suitable for the application of antagonists, as only T12 showed some control efficacy. In the other two systems all antagonists inhibited *R. solani* to different extents. The rice husk and sawdust compost systems were more effective than with sawdust. Similar results were observed when these substrates were used for commercial cultivations of chrysanthemums. We speculate that the different degress of inhibiton of *R. solani* shown by the antagonists depended on the application method used[1,6]. Although rice husks are not easy to compost because of their high silica content, they could be used without prior treatment for preparation the inocula of antagonists.

Table 4. Control of *R. solani* in chrysanthemum by sawdust compost containing antagonists

Antagonist	Disease incidence (%)
Penicillium sp. CF111	9.2 efgh[1)]
Paecilomyces marquandii CF302	8.0 fgh
Paecilomyces marquandii CF407	15.6 cd
Gliocladium deliquescens F-92	14.1 def
Penicillium vermiculatum F-60	23.3 bc
Trichoderma viride TD	23.3 bc
Trichoderma koningii T2	25.2 b
Trichoderma viride T20	13.8 def
Trichoderma pseudokoningii T33	25.4 b
Trichoderma harzianum TVCN1	6.8 h
Trichoderma harzianum TVCN2	7.9 gh
Trichoderma koningii T12	12.3 efg
Bacillus sp. CB9	22.4 bc
Bacillus sp. CB20	20.6 bcd
Bacillus cereus CB22	13.5 defg
Bacillus subtilis F29-3	9.7 efgh
Control	42.3 a

1) Values within the column not followed by the same letter are significantly different at 5% level (based on DMRT).

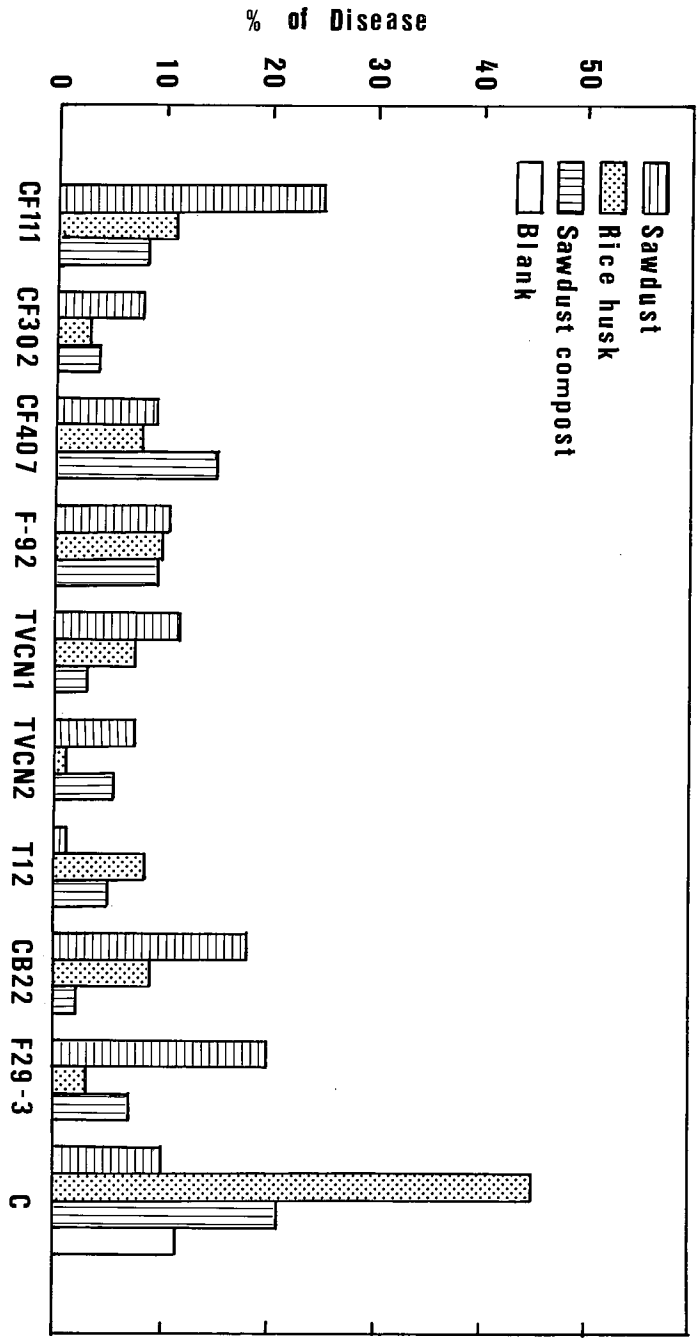


Fig 1. Control of *Rhizoctonia solani* in chrysanthemums by different vehicles containing antagonists.

The disease incidence (Y axis) was reduced by application of different antagonist strains (X axis).

Control of *R. solani* by Antagonist Extracts

Chrysanthemum cuttings were treated with culture extracts of the various antagonists before planting. The result indicated that the extracts protected the chrysanthemums from infection by *R. solani* (Table 5). The control effects of F-92 and CF302 extracts were greater than those of the other antagonists. Inhibiton of the growth of *R. solani* was tested with extracts of some antagonists. Such crude extracts contain antibiotics which inhibited growth of *R. solani.* The antibiotic effects from fungal antagonists were greater than those of the bacterial antagonists. The inhibition mechanisms of the antibiotics that function against *R. solani* must be explained at the physiological level in relation to the mode of action of the antibiotics[3,11]. Our experiments were made in a garden system, and therefore could not give an explanation.

CONCLUSION

The basal stem rot disease in chrysanthemum caused by *R. solani* can be controlled by several antagonistic microorganisms in three ways: (1) by coating chrysanthemum cuttings with the antagonists; (2) by application of solid additives of antagonists to soil when chrysanthemum cuttings are planted and (3) by treatment of chrysanthemum cuttings with extracts from antagonists. Control results differed with the application method used. Our experiments indicated that all the antagonists tested inhibited infection by *R. solani* and that the efficacy of prevention depended on the application method used. A solid additive that contained the antagonist was the best means for applying the antagonist to control *R. solani.* The advantages of the solid inocula are ease of handling and high reproducibility, though its preparation takes a long time. Coating chrysanthemum cuttings with antagonists was better than treating them with extracts of antagonists.

Control of *Rhizoctonia* disease by antibiotic producing antagonists has been evidenced. The disease may be controlled more effectively by improving the efficiency of antagonists with genetic manipulation in the future.

Table 5. Control of *R. solani* in chrysanthemums by crude extracts of various antagonists

Antagonist	Disease incidence (%)
Penicillium sp. CF111	65.5 bc[1)]
Paecilomyces marquandii CF302	52.3 c
Paecilomyces marquandii CF407	63.6 bc
Gliocladium deliquescens F-92	51.9 c
Trichoderma harzianum TVCN1	62.9 bc
Trichoderma harzianum TVCN2	69.5 ab
Trichoderma koningii T12	59.7 bc
Bacillus cereus CB22	66.4 bc
Bacillus subtilis F29-3	81.2 a
Control	71.3 ab

1) Values not followed by the same letter are significantly different at 5% level (based on DMRT).

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摘　要

陳昇明 1991 抗生拮抗菌對菊莖腐病菌之生物防治　植保會刊 33:56～62。（國立中興大學植物學研究所）

以麴菌（*Aspergillus*）、黏帚黴菌（*Gliocladium*）、擬青黴菌（*Paecilomyces*）、木黴菌（*Trichoderma*）和芽胞桿菌（*Bacillus*）等抗生拮抗菌，對立枯絲核菌（*Rhizoctonia solani*）感染之菊莖腐病，從事防治試驗。實驗結果顯示全部拮抗菌均具有防治菊莖腐病之效果。用於土壤添加物或包埋材料之拮抗菌，以固體培養基繁殖者優於液體培養基。菊苗如果以拮抗菌萃取液處理，則可防止其感染莖腐病。拮抗菌對菊莖腐病之防治效果，則因使用拮抗菌種類和施用拮抗菌方法之不同，而有差異。

（關鍵字：生物防治、菊莖腐病、立枯絲核菌、拮抗菌、麴菌、黏帚黴菌、擬青黴菌、木黴菌、芽胞桿菌）

土壤病原生態與防治研討會專刊 63~71, 1991

利用拮抗菌 *Trichoderma koningii* 對紅豆根腐病之生物防治

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摘　要

劉顯達 1991 利用拮抗菌 *Trichoderma koningii* 對紅豆根腐病之生物防治　植保會刊 33:63～71

紅豆根腐病爲土壤病原菌 *Rhizoctonia solani* AG-4 引起之病害，防治不易。由土壤中篩選出强拮抗性之眞菌 *Trichoderma koningii* 對本病菌具重寄生作用，會纏繞及分解 *R. solani* 菌絲。利用化學誘變劑處理拮抗菌，得到一個耐藥性菌系 T12-R33-D25，該菌可耐 Benlate 至 1000 ppm (a.i.) 且於植物之根部拓殖能力顯著增加。利用稻殼米糠培養拮抗菌經十天後每克產孢量達 10^9 可作爲田間防治應用之量產基質。於紅豆植穴中添加約 1 g 稻殼米糠拮抗菌培養物或以拮抗菌孢子懸浮液包覆紅豆種子上，顯著增加紅豆之健康植株數約 56 至 14%，每株產量也增加。如同時添加其他機質，根腐病之發病率也會降低，但和單獨添加拮抗菌處理並無差異。拮抗菌懸浮液處理種子之技術較爲簡易可用來大面積田間推廣紅豆根腐病之生物防治。

（關鍵字：生物防治 *Rhizoctonia solani* 、 *Trichoderma koningii* 、紅豆）

紅豆根腐病

紅豆爲高屏地區之重要多作，年產總值近十億新台幣，然紅豆生育全期均會受到土壤病原菌 *Rhizoctonia solani* AG-4 爲害，影響產量至鉅。*R. solani* 爲土壤病原菌，於土壤中殘存期長，腐生能力强，寄主範圍廣，防治困難，本菌爲害紅豆，造成紅豆初期種子腐爛，或萌發出土前及出土後之猝倒病（pre or post-emergency damping-off），或造成幼苗或成株之根腐病（root rot），一般以藥劑防治難達到經濟性之防治目標，且易造成環境污染，故以生物防治技術作爲防治策略方爲適切可行之途徑[1,4,10,15]。

拮抗菌與生物防治

以 *Trichoderma* spp. 作爲拮抗微生物來防治植物病害之研究，近年來頗受植物病理學者重視，亦發表了不少報告。例如土壤病害，植物地上部器官及儲藏期病害之生物防治。然只限於實驗室、溫室或小型田間試驗能成功，眞正推廣作爲田間防治者，則尚待努力與突破。植物病害之發生與流行和環境、時間關係密切，某些地區某些病害會特別嚴重，反之，某些地區之某特定病害卻很少，這其中可能意謂者生態系中自然生物防治之存在，植物病理學者若要從其中去探索何種因素控制著這生物防治，實需投注更多心血，從各種角度去研究，並加

以評估。本人曾報告 *R. solani* 之抑病土（suppressive soil）之主因乃由於 *Trichoderma* sp. 族群密度之增加[12]。Hadar, Henis 及 Chet 氏等報告以 *Trichodermar* spp. 防治 *R. solani* 造成之蕃茄猝倒病、康乃馨根腐病均有優良之效果[4,6,7]，Elad 氏更指出 *Trichoderma hazianum* 對菜豆（*Phaseolus vulgaris*）之 *R. solani* 及 *Sclerotium rolfsii* 二種病菌亦有生物防治之功效[5]。此外眞菌對 *R. solani* 具有拮抗性之報告有 *Aspergillus niger* 、*A. flavus* 、*A. candidus* 、*Gliocladium roseum* 、*Trichoderma viride* 、*Corticium* sp. 、*Chaetomium cupreum* 、*Laetisaria aivalis* 、*Gliocladium virens* 、*Verticillium biguttatum*. 拮抗細菌者有 *Bacillus subtilis* 、*B. uniflagellatus* 、*Pseudomonas fluorescens* 等。此等拮抗生物之作用大部分均爲於實驗中或溫室盆栽試驗表現出其生物防治效果，僅有少數如 *T. harzianum* coating 在鳶尾之球莖，*T. hamatum* coating 在棉花種子或以 *Trichoderma harzianum* 混入消毒之土壤，種植蕃茄等在田間獲致對 *R. solani* 有生物防治作用。生物防治於田間能否獲得成功，田間環境影響甚鉅；拮抗菌族群之建立、繁殖、殘存之生態條件，*R. solani* 之菌絲，分佈及感染源形態，密度殘存等在在均會影響生物防治之運作。

Beagle-Ristaino 以 *Trichoderma viride* [T-1-R9] 及 *Gliocladium virens* [G1-21] 作拮抗菌成功的於溫室及田間防治馬鈴薯菌核病，發病率減少 54～89%，而其所使用 T-1-R9 菌株對 benomyl 具抗藥性，爲成功之重要因素。本試驗所篩選之拮抗菌 T12 、TC11 、TVCN1 、T2 、TD 及 T33 對 benomyl 均無抗性，於 1 ppm 濃度下生長完全受抑制。因現行之苗圃或本田期，農民大量施用 benomyl 來防治病害，爲期添加之拮抗菌能發揮生物防治作用，篩選抗藥性之拮抗菌爲重要課題[2,13]。

篩選強拮抗性之優良菌株

由紅豆田間土壤及紅豆植株包括根系部位之組織，利用土壤稀釋法，組織表面培養法及尼龍網誘菌法等[11,12]分離到近百種菌株（細菌與眞菌），利用對峙培養及玻璃紙抗生法先行測試各菌株對 *R. solani* AG-4 之拮抗能力，得到拮抗眞菌 *Trichoderma koningii* T-12 、*T. harzianum* TC-11 及拮抗細菌 A003 、A020 、A036 、A045 、A047 及 A090 等菌株。其中 T-12 及 TC-11 對 *R. solani* 之重寄生現象尤爲明顯，會纏繞及分解該菌絲，在對峙培養時，即使兩種菌絲尚未接觸，*R. solani* 菌絲前端細胞就表現出不正常的生長現象，如細胞縊縮、細胞質顆粒化等。*Trichoderma* 和 *R. solani* 在土壤中彼此間族群密度消長則利用選擇性培養基配合土壤孔土片法測定之[5,8,9,12]。

拮抗菌抗藥性之誘變

由於 *Trichoderma* 拮抗菌對於 benomyl 藥劑非常敏感，1～10 ppm 即會明顯抑制 *Trichoderma* 生長，故如需施用該拮抗菌於田間作爲生物防治，能順利建立族群，於田間繁殖殘存具有耐藥性或抗藥性是必須的。將 T-12 及 TC-11 菌株利用 uv 照射處理或是以化學誘變劑 DES 、EMS 及 N_aNO_2 處理得到一些菌株（表一），再一步測試其耐藥性時，發現 T12-R33-D25 菌株對 benomyl 之抗藥性最好（表二），而對 PCNB 及 Neo Asozin 之抗藥性則和親本型 T-12 則無差異（圖一），而此抗藥性菌株 T12-R33-D25 對 *R. solani* 之重寄生作用或抗生作用並無衰退或減少（表三）。本試驗利用物理及化學誘變法處理拮抗菌 *Trichoderma koningii* 及 *T. harzianum*，成功地由 DES 處理得到 T12-R33-D25 菌株可容忍 Benlate 1000 ppm，比目前發表之 T1-R9 及 T95-GA[3,13] 耐藥性還高，且產孢能力十分正常，T95-GA 只會在含 benomyl 之培養基才會正常產孢。

拮抗菌於紅豆根部拓殖現象

一般而言，眞菌比細菌於植物根部表面拓殖能力（root colonization）較差，若應用拮抗菌作爲植物根部病害之生物防治，該拮抗菌之根部拓殖能力影響其防治效果很大。利用 Randhawa 氏之幼苗測試法[14]及鋁箔管法[3] 二種方法來檢定拮抗菌根部拓殖能力時，發現抗藥性拮抗菌之拓殖能力大幅提高（表四），此現象之發現和 Baker 氏之報告不謀而合，至於

爲何抗藥性之拮抗菌會有此特異性，其作用機制爲何現仍探討中。

紅豆根腐病生物防治效果溫室測試

溫室盆栽試驗中，發現添加T12於病土中，紅豆根腐病之發病率由47%降爲22%，若添加T12-R33-D25於病土中則更降爲9%，若僅添加chitin（0.1%），或CMC（0.1%），或C_aSO_4（0.1%），或稻殼（0.1%），或蝦殼粉（0.05%）於病土中，則只有CMC添加處理之發病率稍爲降低，其他則無差異（表五）。由此顯示拮抗菌添加處理之生物防治效果十分明顯，特別是T12-R33-D25處理發病率尤低，其效果應和其根部拓殖能力有關。而病土中添加CMC也可以降低發病率，可能和促進土壤中自然存在微生物繁殖有關，特別是易於利用及分解纖維素之微生物。

表一、利用物理及化學誘變處理拮抗菌 *Trichoderma* spp. 所得到新菌株之數目

Table 1. The number of biotypes of antagonistic *Trichoderma* spp. obtained from physical and chemical mutation treatments

		Biotype			
		UV[1]	DES[2]	EMS[2]	$NaNo_2$[2]
Trichoderma harzianum	TC11	15	12	24	6
Trichoderma koningii	T12	17	46	73	11

1) Conidial suspensions were irradiated under 255 nm wavelength at the density of 190 W/cm^2 for 2-4 hr.

2) Diethyl sulfate (DES), ethyl methanesulfonate (EMS) and sodium nitrite ($NaNO_2$) were applied as chemical mutagens.

表二、拮抗菌 *Trichoderma* spp. 耐藥性菌株於含不同濃度benomyl培養基之生長菌落直徑

Table 2. Colony diameter[1] of mutants of antagonistic *Trichoderma* spp. grown on various concentrations of benomyl

Biotype[2]	Benomyl concentration (μg/ml)										
	0	1	10	20	50	100	200	400	600	800	1000
T12	90	7.3	7.2	—	—						
TC11	90	8.7	—	—							
TC11-R5	90	81	35	—							
T12-R33	90	90	63	37							
T12-R33-D19					89	63	32	30	27	26	—
T12-R33-D25					90	62	38	41	37	34	26
T12-R33-D31					90	54	31	30	29	26	—
T12-R33-D75					79	43	27	24	23	21	—
T95-GA					80	24	19	17	—		

1) Antagonistic fungi were cultured on PSA plate with various concentrations of benomyl, incubated at 28℃, and colony diameters measured in mm after 72 hr incubation.

2) T12 isolate is *T. koningii,* TC11 isolate is *T. harzianum* and T95-GA also *T. harzianum* (from R. Baker).

表三、*Trichoderma koningii* 抗 benomyl 突變菌株對 *Rhizoctonia solani* 之重寄生及抗生作用

Table 3. Mycoparasitism and antibiosis assay of benomyl resistant mutants of *Trichoderma koningii* against *Rhizoctonia solani*

Biotype isolate	Hyperparasite[1)]		Antibiosis[2)]
	Hyphae coiling	Hyphae lysis	Colony diam. (mm)
T12	+	+	17.5
T95-GA	+	+	44.9
T12-R33	+	+	18.4
T12-R33-D19	+	++	23.5
T12-R33-D25	+	++	15.5
T12-R33-D31	+	++	20.3
T12-R33-D36	+	+	20.7
T12-R33-D37	++	+	20.3
T12-R33-D75	+	+	15.6
T12-R33-D83	++	++	14.2

1) ++, + means degrees for hyphae coiling by *Trichoderma* and hyphae lysis of *Rhizoctonia* assayed by dual culture method.

2) Assayed by cellophane membrane method.

表四、拮抗眞菌及細菌於蘿蔔根部拓殖情況

Table 4. Rhizosphere colonization of antagonistic fungi and bacteria on the radish roots

Seed coating antagonist	Root tip colonized[1)] by mutant	Depth of root colonized[2)] by antagonist (cm)
A003	+	2
A020	+	8
A036	+	8
A045	−	2
A047	−	1
A090	−	2
TC11	−	2
T12	−	3
T12-R33	+	8
T12-R33-D25	+	8
T95-GA	+	8

1) Assayed by Randhawa's seedling bioassay method; + = colonization, − = no colonization.

2) Assayed by Chao's aluminum foil tube method with sterilized sandy loam soil.

表五、土壤中添加物及拮抗菌對紅豆根腐病之生物防治效果

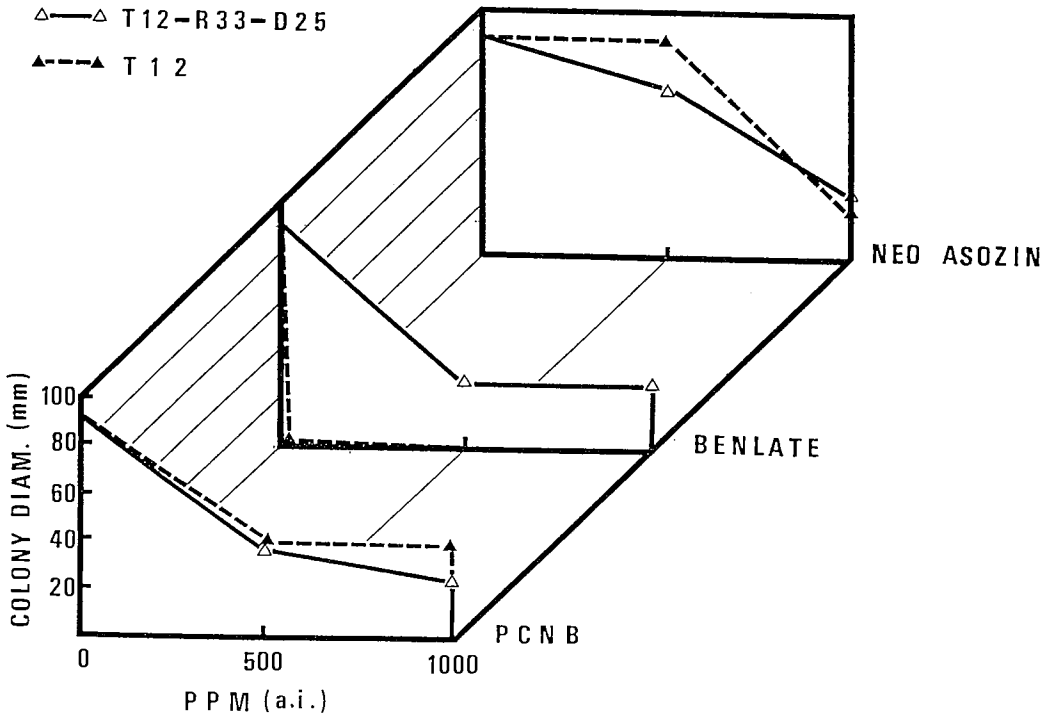
Table 5. Biocontrol of adzuki bean root rot by soil amendment with additives and antagonists

Amendment treatment	Disease incidence (%)[1]			
	Re[2]	Re + T12[3]	Re + D25[3]	Control
Chitin 0.1%	37 ab	17 ab	7 b	15 a
CMC 0.1%	29 b	18 bc	9 ab	8 b
$CaSO_4$ 0.1%	44 a	28 a	14 a	9 b
Rice husk 0.1%	44 a	28 a	12 a	12 a
Shrimp shell 0.05%	32 ab	20 b	15 a	11 ab
Control	47 a	22 ab	9 a	5 b

1) Disease severity was the average of five replicates each treatment, and each replicate had 10 pots planting 10 seeds in each. Data in each column followed by different letters were significantly different according to Duncan's multiple range test ($p = 0.05$).

2) Soil infested with CPS inoculum of *Rhizoctonia solani* Re isolate at the density of 5 mg/g soil.

3) Soil also amended with the conidia of *Trichoderma koningii* T12 or T12-R33-D25 harvested from rice husk media culture at the density of 10^7 conidia/g soil.



圖一、拮抗菌 *Trichoderma koningii* T12 菌株及耐藥性突變菌株 T12-R33-D25 對 PCNB, Benlate 及 Neo Asozin 三種農藥之殺菌反應

Fig 1. The fungicidal response of antagonistic fungi T12 (*Trichoderma koningii*) and T12-R33-D25, a benomyl resistant mutant, to PCNB, Benlate and Neo Asozin fungicides.

拮抗菌量產基質及方法

Papavizas 指出添加 *Trichoderma* 於土壤中作爲生物防治因子時，以厚膜孢子發芽較優，殘存期也長[13]故探討適當且價值低廉之培養基質，促進拮抗菌能同時產生大量之厚膜孢子及分生孢子，且培養方法簡易能達到量產目的。

稻殼和米糠混合製成之培養基（含水量 50% W/W），以 2：1 (W/W) 之比例，T12 分生孢子濃度最高可達 2.5×10^9 conidia/g，T12-R33-D25 於 4：1 或 2：1 之混合比例中，分生孢子濃度無顯著區別，均約可達 $10^8 \sim 10^9$ condidia/g，而 T12-R33-D25 產生厚膜孢子之能力於 4：1 或 2：1、1：4 均較 T12 爲少，於 2：1 比例之培養基厚膜孢子可達 $5 \sim 6 \times 10^7$ chlamydospores/g（圖二），利用酒糟（米糟），糖蜜及酵母作液體培養對 T12 及 T12-R33-D25 之產孢量無甚差異，唯於米糟中 T12-R33-D25 分生孢子量幾乎達到 10^8 conidia /g，但仍比稻殼米糠培養基產孢量差（圖三）。

目前量產之方法即以耐熱之 PP 袋裝盛稻殼米糠培養基經高壓滅菌後接種拮抗菌孢子懸浮液，於 28℃培養 14 天後備用，另外以其他基質，經酸酵法，或半消毒法培養亦有良好成效，培養物作爲粒劑、液劑及可濕性粉劑，其有效性及儲藏期正探討中。

紅豆根腐病田間生物防治試驗及推廣

民間 76 年冬作，於內埔、潮洲二地各一甲地進行試驗，土壤中有添加病原菌處理，拮抗菌以植穴添加及種子處理二種施用方式，結果發現以拮抗菌添加處理效果最好，健株較未添加拮抗菌處理曾加 55.9%，產量增加 28.4%（表六），種子處理效果未盡理想。民國 77 年及 78 年冬作再進行田間試驗，唯不再添加病原菌作爲接種源，種子處理之孢子懸浮液也改進爲添加 2% CMC 及 3% arabic gum，孢子濃度提高爲 10^9 孢子 /ml，每公頃種子量 70 ～ 75 kg 約需 2.5 l 孢子懸浮液拌種處理後涼乾即可播種。結果發現拮抗菌添加及拌種二處理均顯著增加紅豆產量，每公頃約 1200 公斤至 500 公斤（表七），因利用拮抗菌拌種成本低廉，施用簡易，現正配合紅豆高雄五號品種之推廣實施拮抗菌拌種推廣試驗作不同區域性之觀察比較。

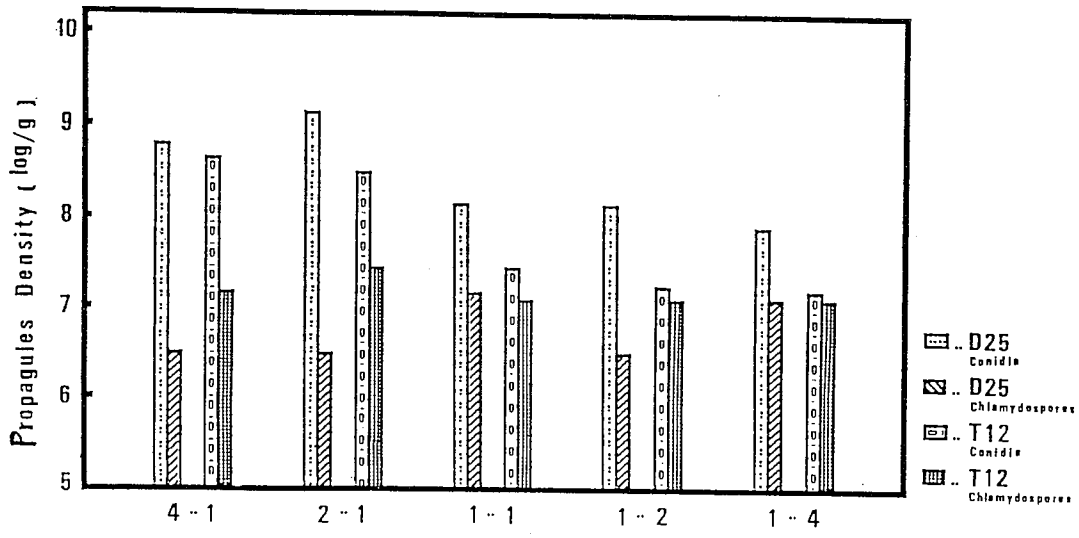
表六、抗藥性拮抗菌 *Trichoderma koningii* D-25 對紅豆根腐病生物防治效果

Table 6. Biocontrol effect of benomyl resistant antagonist *Trichoderma koningii* D-25 against root rot disease of adzuki-bean

Treatment	Plant stand		Yield	
	No/0.1 ha	%	kg/0.1 ha	%
Noninoculated Ck	22019	100 b	169.09	100 b
Inoculated with *R. solani*				
D-25 coating	19455	88.4 ab	156.17	92.4 ab
D-25 amending	28760	130.6 c	193.58	114.5 c
without D-25	16441	74.7 a	145.58	86.1 a

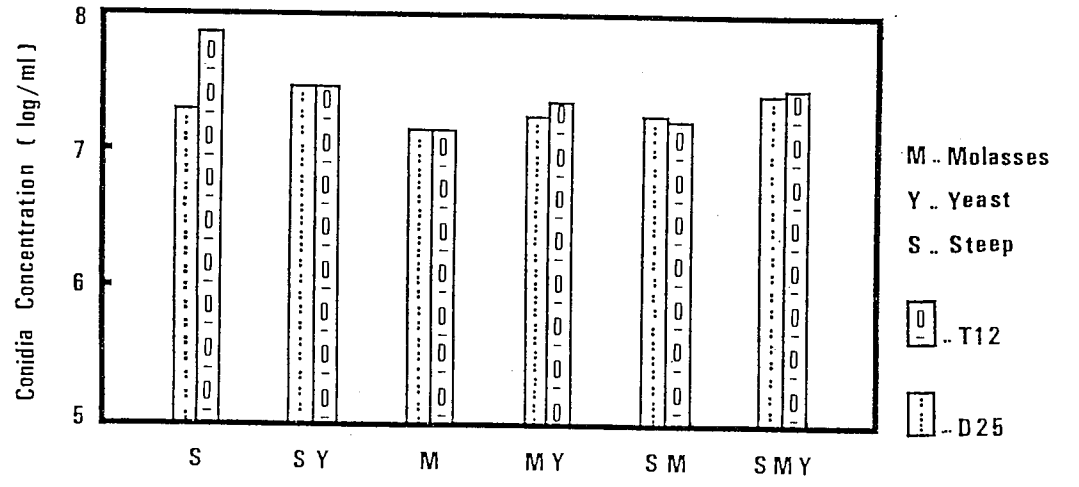
a. CPS inocula of *Rhizoctonia solani* were added to sowing hole at ca. 5 mg per hole. In D-25 amending treatment, 1 g of rice husk cultured biomass with conidia 10^9 per g was amended into hole at the same time. In seed coating treatment, adzuki-beans were dipped into conidial suspension (10^9 conidia per ml) with 1 % CMC for 5 mins and air dry.

b. Values in each column followed by the same letter are not significantly different ($p = 0.05$) according to Duncan's multiple range test.



圖二、拮抗菌 *Trichoderma koningii* T12 及耐藥性菌株 T12-R33-D25 於不同比例之稻殼米糠培養基（28℃，14天）產生分生孢子及厚膜孢子之情形

Fig 2. The sporulation of conidia and chlamydospores of *Trichoderma koningii* T12 and benomyl resistant isolate, T12-R33-D25 cultured on various formulating rice husk-bran media (ratio of rice husk to bran) at 28℃ for 14 days incubation



圖三、拮抗菌 *Trichoderma koningii* T12 及耐藥性菌株 T12-R33-D25 於米糟、糖蜜、酵母培養基之產孢量

Fig 3. The sporulation of conidia and chlamydospores of *Trichoderma koningii* T12 and benomyl resistant isolate, T12-R33-D25 cultured on rice steep, molasse of yeast extract at 28℃ for 14 days incubation

表七、抗藥性拮抗菌 *Trichoderma koningii* D-25對紅豆根腐病田間生物防治效果

Table 7. Biocontrol effect of *Trichoderma koningii* D-25 on adzuki bean root rot disease, caused by *Rhizoctonia solani*

Treatment[2)]	Dried wt. (g/plant)				Yield (g/plant)				Yield (kg/ha)			
	1[1)]	2[1)]	3[1)]	av.	1	2	3	av.	1	2	3	av.
Soil amending	44.6	52.8	74.4	57.3 b[3)]	7.8	9.3	11.8	9.6 b	4026	4135	4517	4226 c
Seed coating	58.1	50.7	60.8	56.5 b	9.2	8.5	9.9	9.2 b	3243	3158	4123	3508 b
CK	34.7	28.2	43.5	35.5 a	5.8	4.6	7.3	5.9 a	3141	2783	3127	3017 a

1) Plot 1 and 2 were 1 hectare each, plot 3 was 2 hectares and each plot had five replicates designed randomly for field trial.

2) About 5 g of antagonist biomass were put into sawing holes in soil amending treatment and conidial suspension at density of 10^8 conidia per ml with 2% carboxymethyl cellulose and 3% arabic gum was used in seed coating treatment.

3) The data in each column following the same letter are not significantly different according to Duncan's Multiple Range Test ($p = 0.05$).

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ABSTRACT

Liu, S. D., 1991. **Biological control of adzuki-bean root rot disease caused by *Rhizoctonia solani*.** Plant Prot. Bull. 33:63-71. (Department of Plant Protection, National Pingtung Institute of Agriculture, Pingtung, Taiwan, Rep. of China)

The root rot disease of adzuki-bean (red bean, *Phaseolus angularis*) caused by *Rhizoctonia solani.* is an important and destructive adzuki-bean disease in Taiwan. Conventional chemical control is impractical. Biological control or *R. solani* with antagonist(s) may be and alternative for control of the disease induced by this soil-borne pathogen. By in vitro dual culture and antibiosis bioassay, two antagonistic fungi, *Trichoderma harzianum* (TC11) and *T. koningii* (T12) were shown to be strongly antagonistic to *R. solani* from sreening tests. To improve the biocontrol efficacy and surcival in field where a number of fungicides were constantly sprayed, TC11 and T12 were induced to be benomyl resistant. A new strain (T12-R33-D25) obtained was resistant to 1000 μg/ml benomly, without decreasing mycoparasitic, lytic ability or antibiosis against *R. solani* compared with the parent strain. A rhizosphere competent phenomenon and growth promotion effect were observed in seed coating or soil amendment with T12-R33-D25. With soil amending of culture biomass ca. 1 g into sawing hole or seed coating with conidial suspension, the healthy plants and yields of adzuki-bean significantly increased compared with non-biocontrol treatment in field trials at Pingtung and Kaohsiung from 1986 to 1990. *R. Solani* was successfully controlled by these two delivery systems with benomyl resistant antagonistic *T. koningii*, but application by seed coating consmued less labor hours and culture produce of antagonist is now under extension to the bean grower.

(Key words: Biocontrol, *Rhizoctonia solani, Trichoderma koningii*, adzuki-bean)

土壤病原生態與防治研討會專刊 72~79, 1991

台灣植物青枯病菌之生態與防治

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摘　要

徐世典 1991 台灣植物青枯病菌之生態與防治　植保會刊 33:72～79

由 *Pseudomonas solanacearum* 引起的青枯病是植物最嚴重的細菌性病害之一，在台灣已記載被本病爲害的作物計有番茄、煙草、馬鈴薯、甜椒、茄子、落花生、天堂鳥花、草莓、紫蘇、蓖麻、胡麻等，最近在蘿蔔、康富利及番荔枝上也被證實有本病的發生。台灣存在的青枯病菌菌株目前已知者都屬於 race 1，但其中可分爲數種病原型；生化型則屬於 biovar 3或 biovar 4，極少數菌株爲 biovar 2。青枯病在夏季或高溫多濕季節發生嚴重，而冬季較少發生。土壤濕度高利於發病，濕度低病害輕微。土壤質地與病害發生無密切關係，但台灣有多處土壤爲抑菌土及抑病土。青枯病菌在土壤中的存活受土壤因子的影響，潮濕土壤適合其存活，而乾燥及淹水土壤不利其生存，酸性土壤也較不適宜。如以田間傳播方式造成發病率的不同來分，台灣的青枯病有三種類型。第一類爲茄科等大多數植物上的青枯病，主要以土壤傳播式的方法而引起，土壤中病菌的濃度及分佈決定田間的發病率；第二類爲草莓上的青枯病，主要經由帶病菌的移植苗傳播而造成，幼苗帶菌率的高低決定田間病害發生的程度；第三類爲紫蘇上的青枯病，主要藉著機械傳播式而引起，病菌經採收機械由病株迅速蔓延於大面積的健株上。青枯病有多種可行及正待發展的防治方法，包括抗病育種、抗病根砧嫁接、施用土壤添加物、輪作、生物防治、使用健康種苗、農具消毒及其他耕作措施，但爲因應上述傳播方式之不同，施用於某一特定作物上的防治策略之重點應有所差異。

（關鍵字：青枯病、青枯病菌、寄主植物、菌系、存活、傳播、環境因子、防治）

緒　言

由青枯病菌（*Pseudomonas solanacearum* (Smith) Smith）引起的青枯病（bacterial wilt）是植物最重要的細菌性病害之一[19,34]。本病發生在二百多種植物上，造成罹病植物的萎凋枯死，對農作物的生產損失甚鉅[34]。本病分佈也很廣，熱帶及亞熱帶地區尤易發生。台灣氣候高溫多濕，適合青枯病發生，多種經濟作物受其爲害，常爲作物栽培上的限制因子。青枯病菌雖能感染爲數衆多的植物，但病害發生本質及病菌生態特性可能因植物種類、病菌菌系及發生地區的不同而有所差異[18,19,27]。爲解決本病的爲害，首須對特定地區的病害及其病菌族群有詳細瞭解後，才能研擬有效防治對策。本文就十數年來在台灣所做的研究結果，作一綜合論述。

分佈及寄主植物

青枯病分佈廣泛，遍及熱帶、亞熱帶及溫

暖的溫帶地區[34]。在台灣，各栽培地區都會發生，中南部尤其普遍[3]。青枯病菌的寄主範圍也很廣，已記載的寄主包括30多科200多種植物[34]，但病菌菌株間的寄主範圍差異很大，有些菌株能感染多種植物，而有些菌株則僅侵害少數特定的植物[19]。在台灣田間自然發生被爲害的植物，迄今已知者共有番茄、煙草、馬鈴薯、甜椒、茄子、落花生、天堂鳥花、草莓、紫蘇、蓖麻及胡麻[3,7,8,13,17,32]，最近中部栽培的蘿蔔、康富利及東部的番荔枝也被證實有本病的發生（徐、曾、黃等人，尚未發表資料）。在這些寄主中，蓖麻及胡麻上的青枯病係於1944年記載[17]，但由於這二種植物已不再或很少種植，至少20年來未曾有病害發生的報告。

病菌菌系

青枯病菌是一種複合種類，具有多種菌系，目前廣用於界定菌系的系統主要有二種。一爲Buddenhagen等人[20]提出依病菌菌株的來源及寄主範圍而區分的生理小種（race）系統，另一爲Hayward[26]創議依病菌菌株的生理生化特性，特別是氧化六種碳水化合物產酸能力的差異而區分的生化型或生物型（biovar）系統。根據Buddenhagen等人[20]，青枯病菌有三種生理小種存在，race 1菌株感染番茄、煙草等茄科及其他多種植物，race 2菌株侵害三倍體香蕉及赫蕉（Heliconias），race 3菌株主要爲害馬鈴薯及番茄，而在其他茄科植物上的病原性微弱。隨後的研究又發現另外二種生理小種，一爲在菲律賓由薑上分離的某些菌株屬之，另一爲在中國大陸由桑樹上分離的菌株屬之，因這二類菌株的病原性與上述已知的三種生理小種者不同而被認爲是新生理小種[18,28]。每一生理小種，尤其是race1菌株中，仍有病原性或寄主範圍的差異存在，在各地區可再細分爲不同病原型（pathovar）。依據Hayward分類，青枯病菌則區分爲四種生化型（biovars 1～4）[26]。生理小種與生化型之間並無絕對相關性，但第三生理小種（race 3）都屬於第二生化型（biovar 2）[19]。

在台灣，從各種寄主分離而已測定的菌株都屬於race 1[3,7,13,32]，亦即爲可感染茄科等多種植物的生理小種，其他生理小種則尚未被發現。台灣菌株雖都屬於race 1，但菌株間在不同寄主上的病原性有差異。徐等人[7]從台灣各地不同寄主分離的50個菌株，依其在番茄、煙草、甜椒、茄子、馬鈴薯及落花生等六種作物上病原性的差異，分爲八個病原型。陳[11]測定台灣79個煙草菌株，也可分爲五個病原型。台灣菌株中，由紫蘇分離的菌株較爲特殊，因其雖能感染多種茄科作物及落花生，但茄科及落花生的菌株卻不能感染紫蘇[32]，顯然紫蘇菌株自成一個病原群。台灣菌株，除極少數煙草菌株爲biovar 2外，大多數菌株爲biovar 3，有些菌株則爲biovar 4[11,13,31,32]。病菌在實驗室保存期間可能會產生病原型及生化型不同的變異菌株[22]。

病菌之傳播

青枯病菌有多種傳播方法[19]，在台灣，青枯病發生在10數種作物上，但其傳播特性不盡相同。如以田間傳播方式造成發病率的不同來分，台灣發生的青枯病有三種類型。第一類爲土壤傳播型，發生在茄科及其他大多數植物上的青枯病屬之，引起該等病害之病菌，主要以土壤傳播，爲典型的土壤傳播性病害，存活於土壤中的病菌，經由根部侵入感染而蔓延於植株維管束組織內，致使植株萎凋，土壤中病菌的濃度及分佈決定田間的發病率[12,23]，又病菌可由病株的根部轉入土壤中，而再感染鄰近健康植株，因此病菌也可經由根對根的傳播[4,35]。第二類爲移植苗傳播型，發生在草莓上的青枯病屬之，草莓對青枯病菌具有耐性[24]，幼苗定植後，如方被土壤中的病菌感染，於生育期間不易出現萎凋病徵，直至採收末期少數植株才出現病徵，對草莓的生產影響輕微，但若移植苗在苗圃已被病菌感染，幼苗雖外觀健康，定植於田間後，萎凋病徵便很快出現，造成幼苗枯死，對草莓的栽培影響就大[9]，因此田間嚴重病害的發生主要是因病菌由移植苗傳播造成，而幼苗帶菌率的高低可決定田間發病的程度。第三類爲機械傳播型，發生在紫蘇上的青枯病屬之；病菌由土壤不易爲害紫蘇，但由地

上部則能迅速引起萎凋[10,32]，由於紫蘇在栽培期間，定期以採收機採剪植株上部的枝葉，病害即在採剪後開始發生，並迅速蔓延於田間，致使大面積紫蘇發生萎凋枯死[10,32]，因此紫蘇的青枯病若由土壤中的病菌引起微不足道，但若由採剪傳播則引發嚴重病害問題。

病菌之存活

青枯病菌在自然界存活的機制，還不甚明瞭。在作物栽培季節與季節間，無感病作物存在時，病菌可能存活於土壤，野生寄主或非寄主植物及繁殖材料等處[27,34]，以作爲下季作物的感染源。土壤是青枯病菌主要的存活場所，但其在土壤中存活的長短，至今仍有爭論，已知不同菌系的存活能力有異，其存活期也受土壤因子的影響[27]。在台灣，徐[5]報告青枯病菌（番茄菌株）在土壤的存活與土壤濕度關係密切，乾燥及浸水土壤不利病菌的生存，而濕潤土壤則延長其存活期，例如在一種測試土壤中，乾燥及浸水時，病菌僅存活分別約一及三個月，但含水量爲 15.2 ～ 19.9% 及 30.7 ～ 36.7% 時，則可存活 225 天及 390 天以上。土壤溫度及酸鹼度也影響病菌的存活，病菌在低溫時的生存時間較在高溫時爲長[5,10]，中性土壤較酸性土壤利於病菌存活[5]。土壤中的病菌族群主要來自罹病植株，病菌在感病植株內繁殖後可由根部轉入土壤中。在土壤中雖能存活一段時間，但若無罹病植物存在，病菌族群會逐漸減少，終告消失，其間若種植感病作物，病菌感染植物後產生的族群又再回到土壤中，因此，連續栽培感病作物可使病菌延續其在土壤中的存活期。作物收穫後，病株常被餘留在田間或犁入土壤內。徐[5]曾測定病菌在病株內的存活能力，當番茄病株的莖及根埋入浸水土壤中，數日後病組織內即無病菌的存在，埋入乾燥土壤中也僅生存 14 ～ 28 天，埋入濕潤土壤中則可存活 84 天以上；在無土壤接觸的情況下，相對濕度高於 55% 時，莖組織內的病菌約於一個月後消失，但相對濕度低時可存活八週以上。

青枯病菌的寄主範圍廣泛，除栽培作物外，許多田間野生植物也可被其感染，有些會顯現病徵，有些則不表現病徵[27]。在無感作物栽培的季節裡，這些中間寄主或非寄主植物在病菌的存活上可能就扮演重要角色，同時也關係著以輪作防治病害的成效。台灣目前尚無詳細調查野生寄主的資料，但康[10]從苗栗公館及南投國姓田間採集的 15 種雜草中，大飛揚草，昭和草、紫背草及水蜈蚣的根部可偵測到青枯病菌的存在。

環境因子對病害發生之影響

青枯病基本上是一種高溫季節的病害，因此熱帶及亞熱帶尤其流行。台灣田間之觀察也常發現在夏季或高溫多濕季節青枯病發生嚴重，而冬季較少發生。徐[4]曾報告番茄在不同季節種植後的發病程度，雖然土壤中病菌濃度高時，不同時期發生的病害程度差異較小，但土壤中病菌濃度低時，冬季（ 12 月間）因當時平均最高溫度爲 20.5 ℃及平均最低溫度爲 14.6 ℃，病害發生輕微，而其他季節（ 4 月、 6 月及 9 月間）因平均最高（ 28.6 ～ 29.7 ℃）及平均最低溫度（ 20 ～ 22.1 ℃）較高，病害則發生嚴重。 Mew 及 Ho[36]也報告有些番茄抗病品種在台灣秋季（ 10 月）種植時表現抗病性，但在夏季（ 6 ～ 8 月）時抗性降低變爲中抗或中感性。青枯病的發生顯然受許多環境因子的影響，其中土壤溫度及土壤濕度最爲重要。土壤溫度低於約 20 ℃時，病害很少發生，溫度增高，病害漸趨嚴重[4]。土壤溫度也影響番茄抗病性，有些抗病品種在高溫時變爲感病性，而且病勢發展在土壤溫度高時較溫度低時爲快[37]。土壤濕度高可增加病菌在土壤內的存活，提高感染率及感染後病勢的進展，也有利於病菌由病株釋放於土壤中及在土壤中擴散[19]，因此土壤濕度高，病害發生較嚴重[4]。土壤生物因子如根瘤線蟲也能顯著影響病害發生的程度，陳[12]指出土壤有根瘤線蟲存在時，可提高病菌在煙草根部的群集，促進病菌的感染而增加病害的發生，並且降低抗病品種的抗病能力。

土壤質地與青枯病的發生似無密切關係，因不同質地的土壤包括細砂壤土、砂壤土、壤土及坋壤土經混入病菌後，種植的番茄都嚴重發生青枯病[6]，又由這些土壤 pH 值 (4.4 ～ 7.2) 觀之，台灣大多數栽培作物的土壤 pH 值適合

病害發生。然而台灣存有抑制青枯病菌的抑菌土及抑制青枯病的抑病土，根據 Ho 等人[29]的研究，從台灣各地採集的 126 個土壤樣品中，約有 25% 爲青枯病菌的抑菌土，而測試的 10 個抑菌土中，有 5 個爲番茄青枯病的抑病土。雖 pH 值低的土壤較 pH 值高的土壤不適合病菌的存活，但 pH 值與抑菌性並無絕對相關性[29]。土壤爲何具有抑菌性或抑病性目前尙未明瞭，闡明其機制，將有助於應用抑病因子於病害防治上。

防治對策

抗病育種

在每一種寄主作物上，尋求抗病性是最理想的青枯病防治對策。台灣栽培的各種作物品種多爲感病性，因此多方搜集抗病來源，以育成抗病品種應爲防治青枯病的主要課題。國外育成的抗病品種在台灣高溫多濕季節栽培時，常不表現抗性[36]，因此抗病育種必須當地進行，以育成適合本地栽培的品種。台灣目前僅在番茄及煙草上有抗青枯病的育種，亞洲蔬菜研究發展中心及農林廳種苗繁殖改良場多年來已進行番茄抗病篩選及雜交育種[1,2,36,38]，從世界各地引進的數千品系中，已選出不少抗病材料，由雜交組合中，也得到一些具抗病及耐熱的品系，唯其抗性仍未達理想。菸葉試驗所多年來也進行菸草抗立枯病的育種[14,15]，先後推廣的台菸五號及台菸八號即被認爲具有抗病性，惟田間栽培觀察，病害仍常發生，其抗性仍待改進。除抗病雜交育種外，嫁接於抗病根砧上也可應用於防治某些作物的青枯病[27,34]。最近在台東發現的番荔枝萎凋病，因其寄主爲多年生木本植物，尋求抗病根砧可能是一種較爲有效，可行的防治途徑。

施用土壤添加物

汚染病菌的土壤是青枯病最主要的初次感染源，雖然有些作物上的青枯病菌可以不依靠土壤而傳播，但大多數作物的青枯病是由存在於土壤中的病菌感染而引起，因此，如能消除或減少土壤中的病菌，應能避免或減少病害的發生。施用有機或無機物質於土壤，以降低病菌濃度，常爲防治土壤傳播性病菌的一種措施。鄭及徐[16]報告土壤添加蝦殼粉 0.8% 以上或尿素 0.075% 以上後，青枯病菌濃度於短時間內便有明顯降低的現象，盆栽試驗也顯示土壤分別添加這二種物質有防治番茄青枯病的效果。自從對多種土壤傳播性病害具有防治效果的一種土壤添加物（ S-H 混合物）被發展出來後，Chang 及 Hsu[21,30]曾就該種土壤添加物防治青枯病的可行性作過詳細探討，由溫室試驗結果顯示番茄於種植前七天，添加 0.5% ～ 1.0% S-H 混合物於土壤中具有良好防治青枯病的效果，S-H 混合物各成分中，刪除尿素及礦灰時，會使該混合物失去防病效果，如僅將尿素與礦灰二者混合使用，則表現與 S-H 混合物相同的防治效果，因此尿素及礦灰爲 S-H 混合物中的主要有效成分[21]。 S-H 混合物的防病機制主要由於施用後，能使土壤中的病菌濃度迅速降低。而此種抑菌作用與土壤微生物有關，土壤微生物分解 S-H 混合物後可產生對青枯病菌有毒的物質[30]。 Hartman 及 Yang[25]的田間試驗結果也得知土壤添加尿素與礦灰的混合物後，對番茄的存活率大爲提高。由這些結果顯示土壤添加物具有防治青枯病的潛力，爲另一項可行的防治措施。

使用健康種苗

苗床土壤若含有病菌，培育出的幼苗，有些外觀雖無病徵，但可能已被病菌感染，移植於本田後，病害隨著發生，因此，應避免在發病地區作育苗圃。選擇無病菌汚染的土壤，培育健康幼苗，可阻止病菌由幼苗傳播而引起的病害。使用健康苗在防治草莓青枯病上特別重要，根據許[9]1984 年在苗栗大湖草莓栽培後期三處罹病田調查的結果，植株平均發病率雖僅爲 1.44% ，但植株已被病菌感染的平均百分率可達 32.2 ，這些外觀健康但已受病菌感染的植株若留作母株，其走莖（ runner ）所形成的幼苗約有 40% 帶有病菌，移植於田間後，病徵很快便出現，造成幼苗枯死，但如幼苗健康，即使定植於罹病田，萎凋病徵也很少發生，可見使用健康苗可減少青枯病菌在草莓上的爲害。許[9]也指出原罹病田在隨後二年若種植由高冷地無病區培育的健康苗，其栽培後期的植株感染率可由 32.2% 降低至 5.9% ，若種植由罹病

田現地留母株所形成的幼苗，則仍高達 37%，因此草莓栽培使用的幼苗，必須在無病地區培育。台灣雖無實際的研究，馬鈴薯青枯病也可藉著種薯傳播[27,34]，但因馬鈴薯易由土壤中的病菌感染而發生嚴重病害，使用健康種薯在罹病田就無法達到有效的防治目的。

生物防治法

生物防治是一種具有潛力防治土壤傳播性病害的方法。在台灣，Tsai 等人[40]曾由青枯病菌許多菌株中篩選出能產生細菌素（bacteriocin）而無致病性的突變菌株，當番茄幼苗種植前利用這種突變菌株浸漬根部，有防治青枯病的效果，但其效果不能持續至番茄生長後期，此乃因該突變菌株在根部群集（colonization）的能力不强之故。尋求能在根部群集的拮抗菌是發展生物防治法的先決條件之一，作者等人目前正研究以根部群集能力强的螢光假單胞菌（fluorescent pseudomonads）防治番茄青枯病的可行性。螢光假單胞菌是植物根系、根圈及土壤中棲息的重要微生物，能產生數種二次代謝物，對許多植物病原菌的生長具有抑制作用[39]，近年來在國外的研究已顯示多種土壤傳播性病菌可應用螢光假單胞菌加以防治[41]。我們從台灣各地番茄根部分離的近二百個螢光假單胞菌菌株中，由溫室浸根處理試驗發現少數菌株具有防治番茄青枯病的效果，比未處理者可減少約 50% 的發病率；現正研究影響螢光假單胞菌防治效果的因子及促進其在根部群集的方法，期以發展青枯病的生物防治法。

輪　作

台灣尚無輪作對青枯病發生影響的研究報告，由田間觀察及國外報告以非寄主作物輪作常可減少病害發生[27,34]。水稻、玉米、甘蔗、豆類等非寄主作物都可作爲輪作作物，尤其與水稻輪作效果最佳，因土壤在長期浸水狀況下，不利病菌的存活，如爲旱地則可能需要較長期的輪作。實施輪作時，必須確定田間並無野生寄主的存在及輪作後種植寄主作物時，必須使用健康幼苗，才能收到輪作效果。

其他耕作措施

作物的栽培季節如可變動，應選擇秋冬季種植，以逃避最適合發病的高溫多濕季節[4]，同時也應避免在罹病田連續栽培感病作物。作物收穫後，應清除田間的病株及雜草寄主，以減少下季栽培時可能的病菌感染源[5,10]。休耕時田間土壤如能多次翻土日曬，使土壤乾燥，可降低土壤中病菌的濃度[5]。田間使用的農具必須乾淨或作適當消毒處理，以避免病菌藉農具由病株傳播至健株上，此種措施在紫蘇青枯病的防治上尤其重要，因紫蘇青枯病菌主要依靠採收機而傳播[32]。根據 Hong 等人[33]的研究，剪刀剪過紫蘇病株後可連續傳播至 40 棵以上的健株上，但剪過病株的剪刀若浸泡於 75% 酒精或 10 倍 chlorox 溶液後，則能阻止剪刀採剪時的病害傳播；此項研究結果如何實際應用於田間採剪機的操作上，尚待研究設計。

由上所述，青枯病有多種可行或正待發展的防治措施。在某一種作物上的防治，應考慮其病菌的來源及傳播特性，由於傳播方式的不同，採取的防治策略當有所差異。土壤傳播型的病害如茄科等作物青枯病，以採用能減少土壤中病菌濃度的措施爲主；種苗傳播型的病害如草莓青枯病，以使用健康苗爲首要，機機傳播型的病害如紫蘇青枯病，以施用能避免或消除病菌污染農具的措施爲主。但引起一種作物病害發生的感染源可能有多種，傳播方式也可能不只一種，因此綜合抗病性及其他各項可行的措施，仍是防治青枯病最理想的對策。

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ABSTRACT

Hsu, S. T. 1991. **Ecology and control of *Pseudomonas solanacearum* in Taiwan.** Plant Prot. Bull. 33:72-79. (Department of Plant Pathology, National Chung Hsing University, Taichung, Taiwan, R.O.C.)

Bacterial wilt caused by *Pseudomonas solanacearum* is one of the most destructive, widespread bacterial diseases of plants in Taiwan. The disease has been reported to occur on tomato, tobacco, potato, sweet pepper, eggplant, peanut, bird-of-paradise, strawberry, perilla (*Perilla crispa*), castor bean and sesame. Very recently, the disease has also been observed on radish, comfrey (*Symphytum peregrinum*) and sugar apple (*Annona squamosa*). Strains of *P. solanacearum* from various hosts tested are all race 1, but several pathovars differ in host range or pathogencity are found among strains. Most strains are biovar 3, some are biovar 4, but a few tobacco strains are biovar 2. Bacterial wilt in many crops is most severe during summer or warm-wet seasons and is

much less destructive during winter. The disease occurs in various types of soils, and is favored by high soil temperature and high soil moisture content. However, soils suppressive to *P. solanacearum* and bacterial wilt of tomato have been detected. *P. solanacearum* survives much longer in moist soil than in dry or flooded soil. Low pH soils are less favorable for survival of the pathogen than high pH soils. When the major means of pathogen dissemination which affect the disease severity in fields are considered, three types of bacterial wilt can be recognized in Taiwan. The first type is bacterial wilt occurs on solanaceous and many other plants. The disease on these crops is caused mainly by soil-borne *P. solanacearum* and the incidence of the disease is determined by the density and distribution of the pathogen in soil. The second type is bacterial wilt on strawberry. The disease is spread mainly by infected seedlings. The wilting symptom during growing stages of strawberry occurs only on those plants grown from infected transplants, therefore, the disease severity in the field is largely determined by the percentage of strawberry seedlings infected by the pathogen. The third type is bacterial wilt on perilla which is caused by the pathogen transmitted mechanically. Perilla plants rarely become diseased when planted in the infested soil, but wilted easily through stem infection. Young shoots of perilla plants are harvested periodically during the cultivation period by clipping off the top branches of plants with a harvest machine. Because of this practice, the pathogen spread rapidly from diseased plants to healthy plants, causing a high incidence of disease. The control of bacterial wilt has been approached in several ways. The control measures available or underdeveloping include breeding for disease resistance, grafting resistant rootstocks, soil amendment, rotation, biological control, use of healthy planting materials, disinfection of contaminated implements and other cultural practices. However, in view of the different means of pathogen dispersal, the control strategy should vary with the particular crop concerned.

(Key words: bacterial wilt, *Pseudomonas solanacearum*, host plants, race and biovars, survival, pathogen dispersal, environmental factors, control)

土壤病原生態與防治研討會專刊 80~94, 1991

溫濕度及添加物對百合白絹病之影響

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摘　要

杜金池、謝廷芳、蔡武雄 1991 溫濕度及添加物對百合白絹病之影響　植保會刊 33: 80～94

百合白絹病係由 *Sclerotium rolfsii* Sacc. 所引起，以人工接種風乾菌核於種球周圍土壤 1 公分內，得知 5 粒菌核（接種源密度爲 2.6 個菌核 /100 立方公分土壤）即可使百合出現黃化病徵，且被害度會隨著菌核接種數目的增加而增加。適合本菌菌核發芽之溫度爲 20～28℃，若菌核和植株先經 20℃處理再移置於 28℃下，不但可提高其發芽率且可使百合易於遭受白絹病之爲害。最適本菌菌核發芽和菌絲生長之水分潛勢爲－1～－10 bars，低於－20 bars 時會降低其發芽率和生長速率。當溫度由 20℃提高至 28℃時，無論土壤含水量爲 15 或 30%（W/W），在接種四星期後，百合白絹病被害度均達 0.81，只是在 15% 土壤含水量下病勢進展較快速。各種化合物在土壤中抑制菌核發芽之能力以含氮化合物爲佳，亞硝酸鈉在含氮量 125 ppm 時可完全抑制菌核核發芽，碳酸氫銨在 250 ppm，尿素和碳酸銨在 500 ppm，而醋酸銨和檸檬酸銨需高達 1000 ppm 才可完全抑制其發芽。土壤中添加 1%（W/W）之幾丁質、米糠、蔗渣、牛糞和太空包廢棄堆肥等可抑制菌核發芽，其中以幾丁質效果最佳；且添加 0.5%（W/W）幾丁質最能抑制病害發生，其次是 1%（W/W）米糠和牛糞堆肥。關於無機化合物和有機添加物對本菌和病害之影響，文中有詳盡之討論。

（關鍵字：百合白絹病、接種源密度、溫度、土壤濕度、含氮化合物、有機質）

緒　言

爲因應本省農業新變局，政府極力推行精緻化農業，在各地推廣適地適種之高經濟作物，百合即爲其中之一。目前生產之百合以亞洲型雜交百合（*Lilium asiatic* hybrid），東方型雜交百合（*L. oriental* hybrid）和鐵砲百合雜交品種（*L. longiflorum* hybrid）爲主，提供切花觀賞之用。產區主要分佈於本省中部地區，計有台中后里、水湳、軍功、南投埔里、彰化田中和雲林大埤等，栽培面積約 40 公頃且有逐年增加之趨勢。

Sclerotium rolfsii Sacc.（有性世代 *Athellia rolfsii* (Curzi) Tu and Kimbrough）係一多犯性土媒病原菌（soil-borne pathogen）。據 Aycok (1966)[14] 報告得知約可侵害 100 科 500 種植物，幾乎全世界均有病例發生[50]，而以熱帶地區發生最爲普遍[14]。在台灣則經劉和吳氏[7]整理得知其寄主範圍有 45 科 126 種植物，而後又增加了三種觀賞植物[10]、菱角[5]和百合[8]

共計 131 種。

白絹病爲害百合時，造成種球腐敗和地上部黃化萎凋而死亡[8]。很多報告指出高溫多濕利於本病發生[18,35,45]，至於溫濕度如何影響病害之發生則少有研究；另外本菌腐生能力非常强，在土壤中可佔據未腐熟之有機質[12]，菌絲快速生長並形成大量菌核[18]，如盲目施用有機質，無非提供本菌有利的繁殖環境，致使病害更形嚴重，但是一些含氮化合物可有效抑制菌核發芽和存活[2]，進而降低病害之發生[39]。故本文除探討溫濕度對病害發生之影響外，更就無機鹽類化合物和有機添加物對白絹病菌和病害之影響提出討論，以期做爲防治方法之參考。

病害發生情形

1989 年 5 月至 7 月在台中后里、軍功、水滴和南投埔里，同年 10 月至翌年 1 月於軍功和彰化田中等百合栽培區均發現白絹病之發生[9]。本病爲害百合時，菌絲可侵入種球鱗片和莖基部，致使植株下位葉黃化，並逐漸往上位葉發展，嚴重時整株萎凋死亡，且以莖基部爲中心之土表可見白色絹狀菌絲呈放射狀生長，上面產生黃褐至黑褐色菌核，或剝開土壤時，在地下部種球周圍可見白色菌絲束纏繞[8]，並破壞種球鱗片而呈腐敗狀。病害在栽培田中的分布情形不一，大部分爲局部偶發狀況，當病徵開始出現後，如不加以控制，則病勢很快地呈放射狀往外蔓延，形成萬綠叢中一簇黃的景觀。

白絹病菌菌核埋在土壤深度 2.5 公分以下，即可降低其發芽率，而在土深 7 公分時幾乎不發芽[40]。一般百合種植深度爲種球頂部覆土 8～10 公分，但猶可發現種球被本菌菌絲纏化爲害，是否意味著初次感染源並非經由菌核發芽而感染，而是腐生在有機殘體上之菌絲直接侵害所致，則有待試驗加以證實。

接種源密度與病害發生之關係

土壤中菌核存在的密度與病害嚴重程度有直接的關係。Backman 等（1981）[15]利用土盤技術（soil-tray technique）偵測 500 克土壤中菌核數目與甜菜白絹病發生率呈明顯正相關，相關係數高達 0.83 以上。在溫室中，1 公斤土壤內含有 1000 個菌核的接種源密度，可造成約 75% 的大豆幼苗遭受侵害[12]。然而 Punja（1986）[38]在溫室條件下，測試接種源密度在每 100 立方公分土壤中含 2.5 個菌核時，蘿蔔根可 100% 被侵害。兩者之間的差異在於後者所用之單位土壤，以蘿蔔主根周圍土壤爲主（土表距根 3 公分、5 公分土深距根 1 公分內之土壤）。筆者依據 Pauja（1986）[38] 所提有效感染之土壤體積（competence volume of soil）加以改變，而決定接種源密度換算公式如下：

接種源密度＝ 100 N/V

$V = 4\pi/3\ [(c/2\pi + 1)^3 - (c/2\pi)^3] \times n$

N＝接種菌核之數目

n＝百合種球數目

c＝種球周徑

V＝有效感染之土壤體積[38]

栽植二顆周徑約 14 公分之百合種球，並在距種球周圍 1 公分內之土壤接種菌核，結果白絹病被害度隨著接種菌核數目之增加而增加（表一）。5 粒菌核（接種源密度爲 2.6 個菌核 /100 cm^3）接種於百合種球周圍土壤，在第 12 天時即可使百合出現黃化病徵，且隨著時間的增加，被害度亦逐漸提高，直至整株死亡爲止。接種 10 粒菌核時，被害度於第 18 天達到一半。被害度一般皆隨著菌核接種數目之增加而提高，且會提前發病[9]。

溫度對菌核發芽和病害之影響

白絹病菌（*S. rolfsii*）菌核發芽方式有爆發式（eruptive germination）和菌絲式（hyphal germination）兩種[41]。菌核在培養基和田土上的爆發式發芽最適溫度爲 21～30℃，低於或超過此溫度範圍時，發芽率明顯降低[40]。筆者以土壤平板測試菌核爆發式發芽率，得知 16 至 32℃間皆可發芽，其中 20～28℃的發芽率最高，介於 80.95～84.18% 之間，而菌核經由 20 和 28℃交互處理，並未能提高其發芽率（表二）。菌核先於乾土表上 3 天後，再加水潤濕，除了 16 和 20℃處理外，其餘溫度處理下菌核發芽率均有明顯降低現象。但 20℃乾土中先靜置三天後再加水置放一天移至 28℃下則發芽率高達 93.65%（表二）[9]。

表一、接種源密度與百合白絹病被害度之關係

Table 1. The relationship between inoculum density of *Sclerotium rolfsii* in soil and the disease severity of lily southern blight

Sclerotial number	Inoculum density[1] (selerotia/100 cm^3)	Disease severity[2]		
		12[3]	15	18
0	0.0	0.00	0.00	0.00
5	2.6	0.13	0.25	0.31
10	5.3	0.25	0.44	0.50
20	10.6	0.44	0.63	0.69
40	21.2	0.56	0.63	0.81

1) Inoculum density represented number of inoculating sclerotia in competence volume of soil around the 14 cm circum size of lily bulb within 1 cm.
2) Disease was divided into 5 grades, 0 = No yellow, 1 = 1/4 part of plant turns yellow, 2 = 1/2 part of plant turns yellow, 3 = 3/4 part of plant turns yellow, 4 = plant wilts and dies. Disease severity = Σ (scale × number of diseased plant at relative scale) / (4 × total number of plants)
3) Days after inoculation.

表二、溫度對白絹病菌菌核發芽之影響

Table 2. Effect of temperature on germination of sclerotia of *Sclerotium rolfsii*.

Temperature[1]	Germination (%)	
	Wet	Dry→Wet[2]
16	53.97	84.13
20	84.13	84.13
24	84.13	71.43
28	80.95	63.49
32	65.08	41.27
20→28	84.13	93.65
28→20	84.13	58.73

1) The soil plate that contained 20 g dry soil and 21 sclerotia was added with 4 ml distilled water and incubated under different temperature conditions. 20→28 represented the soil plate with sclerotia was transferred to 28 ℃ after 1 day of incubation under 20 ℃, while 28→20, the reverse.
2) Dry→Wet represented soil plate was maintained under dry condition for 3 days, then 4 ml distilled water were added.

將菌核乾燥再濕潤時可促進營養泌出[19,41,47]，Punja 和 Grogan[41]將菌核放在 $CaCl_2$ 乾燥箱中 20 小時後，用水沖洗五小時使菌核乾重量減少 25%，而滲漏出胺基酸和碳水化合物之量最多，這些營養物質可增進土壤微生物活力，而抑制其發芽或殺滅菌核[47]。因此種植前若能將田土翻耕並經高溫暴曬，使土壤乾燥後再加以灌溉，則可降低初級感染源之數量。

白絹病菌在土壤溫度 20～40℃下都可危害水稻，造成苗立枯，而最適病勢進展的溫度爲 25～35℃，其中以 30℃下被害度最嚴重[49]。百合白絹病的發生受溫度的變化影響極大，最適發病溫度爲 28～32℃，如將百合先置於 20℃下一星期再移入 28℃生長箱時，可增加被害度（表三）[9]。百合植株生長的溫度需求以 20℃左右爲佳，但本病在 28℃左右易於發生，其原因可能除了溫度利於病原菌的生長外，植株處於較高溫下而呈弱勢生長，使病原菌有機可乘應屬主因。有關此方面的問題值得進一步探討。

表三、溫度對百合白絹病發生之影響

Table 3. Effect of temperature on the occurrence of lily southern blight

Temperature[1)]	Disease severity[2)]	
	2 wks	3 wks
16	0.00	0.00 c[3)]
20	0.00	0.00 c
24	0.00	0.00 c
28	0.25	0.33 b
32	0.25	0.50 ab
20→28	0.44	0.71 a
28→20	0.00	0.00 c

1) Lily plants were cultured in the growth chamber under different temperatures. 20→28 represented lily plants were transferred into 28 ℃ condition after 1 week of incubation under 20 ℃, while 28→20, the reverse.

2) The rating of disease severity is the same as in Table 1.

3) Values followed by the same letter in each column are not significantly different at $\rho = 0.05$ according to Duncan's multiple range test.

濕度對菌核發芽、菌絲生長和病害之影響

水分潛勢對菌核發芽有所影響，在－1～－10 bars之間，菌核爆發式發芽率分別爲 97.9%和 91.7%，而低於－20 bars時菌核不發芽（表四）[9]。在不同水分潛勢下，菌絲生長情形大致與菌核發芽情形相似，－1～－10 bars 菌絲生長良好，生長速率在 29.3 mm/day 以上，然而低於－20 bars時，菌絲生長速率明顯降低，尤其在－50 bars下菌絲塊於第五天以後才見菌絲緩慢生長（表四）[9]。

土壤濕度與菌核發芽的相關研究很多[11,33,40]。在 25%～75%土壤含水量下菌核發芽率均在 68%以上，但超過 75%含水量時發芽率隨即降低[11]；以水分潛勢Ψ_S而言，最適發芽者爲－2.5～－10 bars之間，低於－10 bars時菌核發芽受阻[40]，與筆者測定水分潛勢對菌核發芽和菌絲生長的結果相符。

土壤濕度與白絹病發生之關係少有研究。百合種植在 30%土壤水分含量之情況下比在 15%時較利於白絹病之發生，接種三星期後之被害度分別爲 0.63和 0.38。土壤水分含量在 15和 30%之間交替變化時亦會促進被害度，其中土壤含水量先維持 30%一星期後再慢慢降至 15%時被害度爲 0.75最高（表五）[9]。此結果說明了田間白絹病總是發生在灌溉後或下雨後，土壤漸乾時。Boyle（1961）[18]指出土壤保持濕度之情況下，對 *S. rolfsii* 之發育有利，並可增加病害之嚴重性。土壤含水量在 20%（W/W）時，本菌腐生能力最高，並隨含水量之增加降低[6]。在 50～75%下由本菌引起

的小麥莖和根腐病比飽和含水量嚴重[44]，而含水量及土壤質地與病害發生之關係密不可分，在排水性良好的砂質土壤[49]和坋質土含量高、保水性佳的土壤，利於本菌營腐生生長[6]，且可增加病害之發生[46]。

溫濕度交感效應對病害之影響

百合生長在20℃環境下，土壤含水量維持15%時，其被害度較30%高，然而在28℃下，則以30%土壤含水量者較高。生長溫度由

表四、不同水分潛勢對白絹病菌菌核發芽和菌絲生長之影響

Table 4. Effect of different solute water potential on sclerotial germination and mycelial growth of *Sclerotium rolfsii* on corn meal agar.

− Bar[1]	Sclerotial germination[2] (%)	Mycelial growth (mm)[3]					
		1	2	3	4	5	6
1	97.9	15.5	52.8	79.8			
5	91.7	15.8	53.5	79.0			
10	91.7	16.0	49.8	74.5			
20	79.2	12.5	36.0	55.0	79.5		
30	45.8	0.0	18.3	29.5	45.0	58.5	75.5
50	0.0	0.0	0.0	0.0	0.0	9.5	11.8

1) The solute potential was adjusted to values between -1 to -50 bars by adding appropriate amounts of KC1 into corn meal agar.
2) Each value represents the mean of five replicates, sclerotial germination was rated after 72 hrs of incubation at 28℃.
3) An 8 mm diameter of mycelial disk (from the 7-day-old colony on PDA) was placed onto the center of medium and the mycelial growth was measured each day after inoculation.

表五、土壤濕度對百合白絹病發生之影響

Table 5. Effect of soil moisture on the occurrence of lily southern blight

Soil moisture[1] (%)	Disease severity[2]	
	2 wks	3 wks
15	0.13	0.38 b[3]
30	0.44	0.63 a
15→30	0.25	0.50 ab
30→15	0.50	0.75 a

1) Soil was adjusted to 15 and 30% MHC by adding appropriate amount of distilled water (determined by calculation after drying soil sample at 105℃ for 12 hrs) and kept moisture with plastic bag. 15→30 represented the soil was maintained at 15% MHC for 7 days and then added with appropriate water to adjust soil moisture to 30% MHC. 30→15 represented soil at 30% MHC was progressively dried by natural way down to 15% MHC.
2) The rating of disease severity is the same as in Table 1.
3) Values follow by the same letter in each column are not significantly different at $\rho = 0.05$ according to Duncan's multiple range.

20℃提高至28℃時，無論土壤含水量爲30或15%，四星期後被害度均達0.81，惟在15%土壤含水量下病勢發展較爲快速。由上述結果可知溫度變化，利於病害發生（表六）[9]。

綜合溫度和土壤濕度交感作用對病害的影響，可清楚地發現土壤濕度的效應不比溫度效應强。也就是說，高溫（28℃）下的被害度比低溫（20℃）下高，無關土壤濕度，且在溫度變化下，土壤濕度只扮演著控制病勢進展速度快慢的角色而已。

無機鹽類化合物對菌核發芽和病害之影響

無機鹽類化合物可直接抑制土壤病原菌之生長[42,48]，尤其是含氮化合物可降低白絹病菌菌核之發芽率[2,13,39]。方和劉1988[2]指出土壤含有10 mM之尿素、氰氮化鈣、硫酸銨、硝酸銨、氯化銨或亞硝酸鹽類時，能顯著抑制本菌菌核發芽，其中尿素、氰氮化鈣和亞硝酸鹽類更可殺死菌核。筆者測試二十一種含氮、磷、鉀、鈣和碳之化合物對土壤中菌核發芽和菌絲生長的影響，結果顯示1%（W/W）量之銨態氮化合物如醋酸銨、碳酸氫銨、碳酸銨、檸檬酸銨、鉬酸銨和硫酸銨等，除硫酸銨外都能完全抑制土壤中菌核發芽，其中前四種化合物尙能完全抑制菌絲生長（表七）；另外，尿素和亞硝酸鈉亦能有效抑制菌核發芽和菌絲生長，但硝酸鈣則否。五種含鈣之化合物以1%（W/W）量加入土壤時，除硫酸鈣能促進菌核發芽外，其餘均可抑制菌核發芽，但效果不若銨態氮化合物。磷酸氫鈉和磷酸氫二鈉二種含磷化合物對菌核發芽之抑制能力以後者較佳。含鉀化合物如氯化鉀和硫酸鉀則以前者效果爲佳。關於含碳化合物以丁二酸（琥珀酸）最能抑制菌核發芽，但對菌絲生長則影響不大（表七）。由上述結果可知各種化合物在土壤中抑制菌核發芽之能力以含氮化合物較佳，故進一步測定含氮量與菌核發芽之關係。亞硝酸鈉在含氮量125 ppm時可完全抑制菌核發芽，碳酸氫銨在250 ppm，尿素和碳酸銨在500 ppm，而醋酸銨和檸檬酸銨需高達1000 ppm才可完全抑制發芽，其他如硝酸銨、硫酸銨、鉬酸銨和明礬雖在1000 ppm含氮量時亦不能完全抑制其發芽（表八）。

表六、在不同溫度下土壤濕度對百合白絹病發生之影響

Table 6. Effect of soil moisture on the occurrence of lily southern blight under different temperature condition

Tamperature[1] (℃)	soil moisture[2] (% MHC)	Disease severity[3]		
		2 wks	3 wks	4 wks
20	15	0.06	0.19	0.31
	30	0.00	0.00	0.13
20→28	15	0.69	0.81	0.81
	30	0.44	0.63	0.81
28	15	0.31	0.38	0.44
	30	0.50	0.56	0.69

1) Lily plants were cultured in the growth chamber under different temperatures. 20→28 represented lily plants were transferred into 28℃ condition after 1 week of incubation under 20℃.

2) Soil was adjusted to 15 and 30% MHC by adding appropriate amount of distilled water (determined by calculation after drying soil sample at 105℃ for 12 hrs) and kept moisture with plastic bag.

3) The rating of disease severity is the same as in Table 1.

不同的含氮化合物在相同的含氮量下爲何對菌核發芽之抑制能力不一？Punja和Grogan（1982）[42]指出在高pH值（約8.6）時銨鹽、碳酸鹽和碳酸氫鹽可殺滅菌核，然而在低pH值（約6.0）時則否，因在高pH值下分別可產生NH_3、CO_3^{2-}和HCO_3^-。另自然土中添加各種氮化合物後，僅氨可提高土壤pH值至9.9外，其他處理均在7.7～8.7之間，但所有處理對本菌生長均有抑制作用，土壤經殺菌後，除氨外對本菌生長則無明顯抑制作用[22]。此現象告知二項事實：1.氨在高pH值下可直接抑制本菌生長，2.氮化合物抑制本菌之能力與土壤中的生物因子有關。但是影響菌核發芽能力的到底是土壤pH值、氨氣或是土壤中的生物因子呢？Punja和Grogan（1982）[42]指出本菌菌核在pH 7以上之不同緩衝液水瓊

表七、不同化合物對白絹病菌菌核發芽和菌絲生長之影響

Table 7. Effects of various chemicals on the germination of sclerotia of *Sclerotium rolfsii*

Chemicals[1]	Sclerotial[2] germination (%)	Mycelial growth (mm)[3]	
		3 days	5 days
Alumium sulfate	18	16.8	T
Ammonium acetate	0	0	0
Ammonium bicarbonate	0	0	0
Ammonium carbonate	0	0	0
Ammonium citrate	0	0	0
Ammonium molybdate	0	13.8	T
Ammonium sulfate	30	29.5	P/A
Calcium carbonate	27	20.5	38.8
Calcium chloride	28	19.5	40.5
Calcium nitrate	23	12.5	47.3
Calcium sulfate	80	24.5	39.5
Calcium superphosphate	30	14.5	T
Citrate	27	14.8	T
Glycerin	17	25.0	P/T
Potassium chloride	2	14.5	42.7
Potassium sulfate	74	20.0	39.2
Sodium nitrite	0	0	0
Sodium phosphate, monobasic	57	22.0	41.0
Sodium phosphate, dibasic	19	21.7	42.0
Succinate	0	26.5	43.5
Urea	0	0	0
Check	63	35.8	60.0

1) 1% (w/w) chemical was added into soil with 20% water content.

2) All values are means of four replicates, with 15 sclerotia per replicate.

3) All values are means of four replicates, plate per replicate contains one wheat seed that has been cultured with pathogen for two months. T = *Trichoderma* spp. P = *Penicillium* spp. A = *Aspergillus* spp.

表八、不同含氮化合物對白絹病菌菌核發芽之影響

Table 8. Effect of nitrogenous compounds on the germination of sclerotia of *Sclerotium rolfsii*

Nitrogenous compound	Germination of sclerotia (%)[1]			
	125[2]	250	500	1000
Alumium ammonium sulfate	75.0	76.7	66.7	50.0
Ammonium acetate	91.7	8.3	4.2	0
Ammonium bicarbonate	87.5	0	0	0
Ammonium carbonate	33.3	29.2	0	0
Ammonium citrate	79.2	45.8	8.3	0
Ammonium molybdate	79.2	58.3	54.2	33.3
Ammonium nitrate	62.5	61.7	58.3	54.2
Ammonium sulfate	83.3	66.7	66.7	37.5
Sodium nitrite	0	0	0	0
Urea	41.7	20.8	0	0
Check	75.0			

1) All values are means of four replicates, with 15 sclerotia per replicate.

2) The nitrogen concentration in soil (ppm N).

脂上，其發芽能力完全被抑制，然在 pH 高達 9.7 時菌核仍存活著。方和劉（1989）[3]也以 pH 10 之碳酸鹽緩衝液水瓊脂測菌核活力，結果乃有 56% 之存活率，因而認爲土壤 pH 值並非是使菌核失去活力之主要因子。既然土壤 pH 值與菌核活力無直接關係，那麼土壤微生物所扮演的角色爲何？將菌核培養在含有尿素、亞硝酸鹽或銨態氮化合物之土壤中，經過一段時間後，可由菌核上分離出大量微生物[4,23]，而認爲氮化合物可當土壤微生物之氮素源，以增強其對菌核之定值[23]。相同的，自然土中加入 100 ppm 氮量的硝酸銨可降低菌核發芽率[13]，此可能爲硝酸銨改變土壤微生物相而對本菌發生拮抗作用[30]。方和劉（1988）[2]指出尿素在殺菌土中對菌核發芽及存活全無影響，但加入 *Trichoderma harzianum* 或 *Fusarium ventricosum* 孢子懸浮液或只加少量尿素酶即能使菌核失去活力；然而 *T. harzianum* 和 *F. ventricosum* 單獨存在殺菌土中，對菌核之發芽及存活無作用。又將菌核培養於殺菌土或水瓊脂培養基上，再曝露於含尿素之自然土中，則菌核可被揮發出的氣體氨所殺滅[3]，直接證明土壤微生物與菌核活力無直接關係，氨才是毒殺本菌的主要因子。雖然土壤 pH 值與土壤微生物對菌核存活無直接效應，但卻直接影響氮化合物在土壤中之分解作用而產生氨氣。硫酸銨添加在酸性土壤中產生氨量比在鹼性土壤中少[3]，對菌核的發芽抑制能力亦較弱[3,20,42]，銨態氮化合物在 pH 8.6～9.5 間才能將菌核殺死[42]。另外當土壤添加尿素後，受到微生物分泌的尿素酶所分解而揮發出氨氣以影響菌核發芽及存活[2]。含氮化合物加入土壤後，除了產生氨氣以外，碳酸鹽和碳酸氫鹽類亦可產生 CO_3^{2-} 和 HCO_3^- 而直接殺死菌核[42]。由於各種含氮化合物對於提昇土壤 pH 值之效力不一[4]，影響了氨氣量之產生[3]，以致不同氮化合物在相同含氮量時，抑制菌核發芽之能力不一。

含氮化合物既然可直接影響菌核活力，因此常被用來防治白絹病的發生。例如氮化合物加入土壤後可減輕落花生及甜菜[23]、尿素防治綠豆[1]和硫酸銨及碳酸氫銨減輕草皮[43]等白絹病之發生。其機制不外乎產生氨氣[22,42]和改變土壤微生物相[23]而達防治之效果。若氮肥能與耕作制度或添加拮抗菌相互配合時防治病害效果更佳。Punja 等（1986）[39]添加含鈣或氮量 112 公斤 / 公頃的硝酸鈣或尿素及含氮量 84 公

斤 / 公頃的碳酸氫銨於蘿蔔田後做深耕處理可有效降低白絹病發生。而硝酸銨鈣和*Trichoderma harzianum*一起加入田土時亦能有效防治花生白絹病[28]。

有機質對菌核發芽和病害之影響

有機物質添加對白絹病菌菌核和病害之影響的相關研究並不多見，但實際上卻極度影響病害發生。土壤中有大量未分解的植物殘體或有機質存在時，極有利於本菌的發育[18]，但燕麥及玉米殘體的水抽出物經殺菌之後可抑制本菌之生長[32]。筆者測試苦茶渣、泥炭苔、木屑、幾可質（蟹殼粉）、米糠、蔗渣、牛糞堆肥和香菇太空包廢棄堆肥等八種有機質對本菌菌核發芽之影響，得知以1%（W/W）量各有機質與土壤混合並加水處理7天後，幾丁質、米糠、蔗渣、牛糞和太空包廢棄堆肥等可抑制菌核發芽，其中以幾丁質處理者效果最明顯；相反的，添加1%（W/W）量之苦茶渣可促進菌核發芽（表九）。另外以不同量之苦茶渣、泥炭苔、木屑和幾丁質處理土壤時，顯示除苦茶渣外其餘處理之菌核發芽率隨著添加量之增加而降低，菌核存活率亦然，其中亦以幾丁質添加可有效降低菌核發芽和存活率（表十）。

Johnson（1953）[25]指出在土壤中添加紫花苜蓿後，可促進細菌的繁殖，增加菌核死亡。土壤添加4%苜蓿粉時，可使本菌菌核在1.5～2個月內全部毀滅，2%時2個月，1～0.4%時約3個月，而未添加者在3個月後僅25%遭受破壞。除了土壤添加有機質後會促進土壤微生物之增量，使本菌菌核遭受破壞而死亡[21,25]外，一些好氣性細菌在分解有機質之過程中，會產生乙烯（ethylene）使菌核不能發芽[16]，然而苜蓿粉在分解過程中會產生乙醛（acetaldehyde）和其他揮發性氣體，促進菌核發芽[36]，而利於微生物分解。Linderman和Gilbert（1969）[27]亦發現植物殘體在分解時會產生促進本菌菌核發芽之揮發性物質如甲醇（methanol）、乙醛、異丁醛（isobutyraldehyde）等。可知有機質添加對菌核有正面的促進發芽和負面的摧毀二項影響。衆所周知幾丁質可誘生大量的細菌和放射線菌[37]，分泌抗生物質以毒害病原菌[31]，然而在白絹病菌方面未曾有人報告其可抑制菌核發芽和存活，筆者測試結果認爲其在防治本菌引起的病害方面潛力雄厚，值得進一步探討。

土壤中有大量未分解的有機質時，所有植物均被本菌殺死，然而大量菌核存在時，即使

表九、有機質添加對白絹病菌菌核發芽之影響

Table 9. Effect of organic amendments on the germination of sclerotia of *Sclerotium rolfsii*

Organic matter[1)]	Germiantion of sclerotia (%)[2)]
Oil tea dreg	85.7
Check	76.2
Peat moss	71.4
Sawdust	71.4
Bagasse	64.6
Compost I	59.1
Compost II	57.2
Chaff	47.9
Chitin	0

1) Soil was amended with 1% (w/w) organic matter and then put 15 sclerotia on it after 7 days of incubation. Compost I was the high rotted cattle manure. Compost II was the half rotted waste of sawdust used for mushroom plastic bag culture.

2) All values are means of four replicates, with 15 sclerotia per replicate.

表十、不同量的有機質添加對白絹病菌菌核發芽和存活之影響

Table 10. Effects of various amount of organic amendment on the germination and viability of *Sclerotium rolfsii*

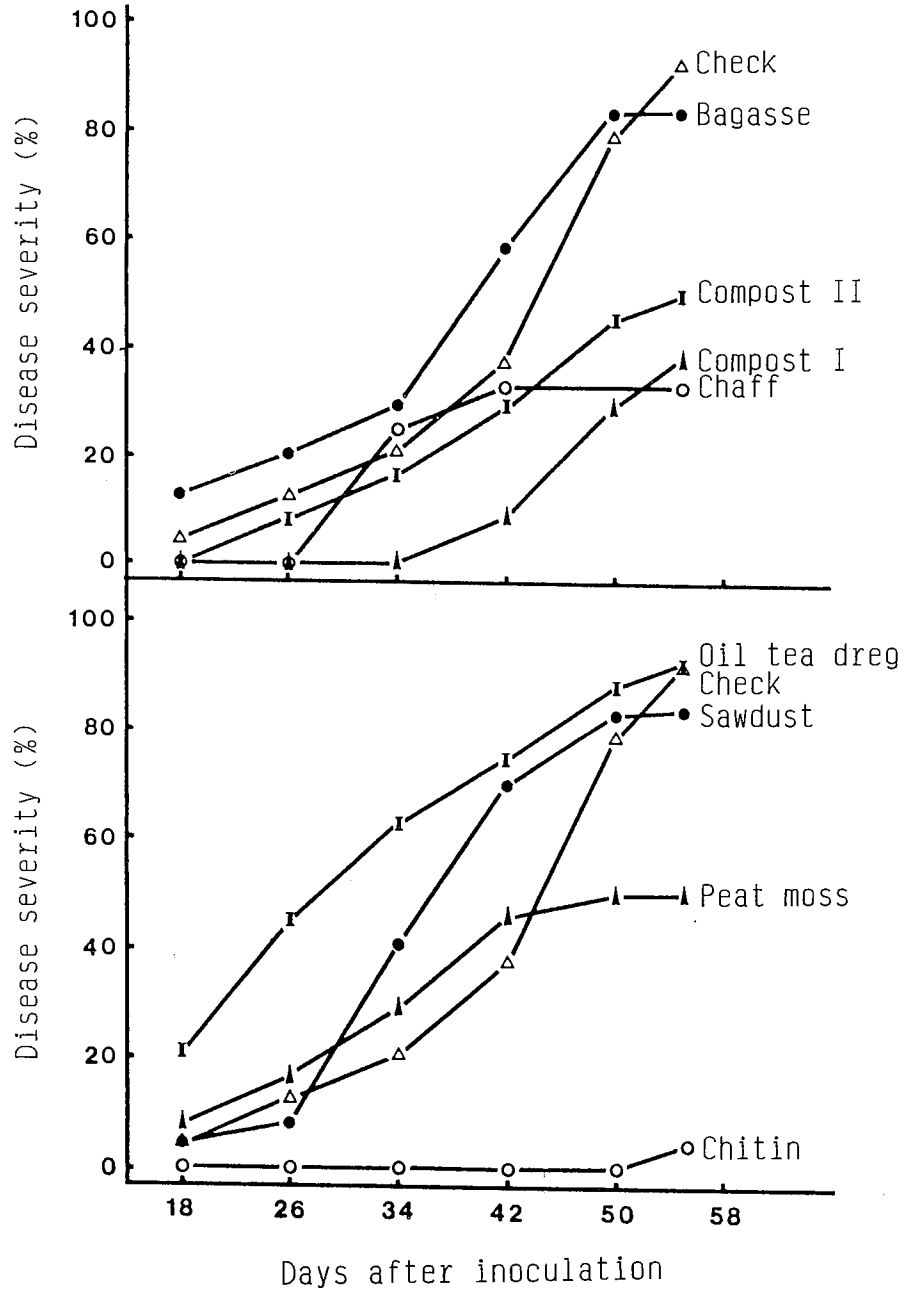
Organic matter	Sclerotial germination/viability (%)[1]			
	0.5[2]	1	2	4
Oil tea dreg	85.7/41.0	85.7/60.0	99.0/40.0	100.0/40.0
Peat moss	87.3/26.7	69.8/30.0	50.8/33.3	39.7/20.0
Sawdust	—	84.1/30.0	54.0/23.3	22.2/ 8.2
Chitin	46.7/45.0	33.3/ 8.0	9.5/ 0.0	0.0/ 0.0
Check	60.3/23.0			

1) All values were means of five replicates, with 21 sclerotia per replicate. Sclerotial germination and viability were examined at 3 and 10 days after organic matter was amended, respectively.
2) Amount of organic matter (gram/100 gram of soil)

是感病植物亦未必被侵襲[24]，無寄主植物之情況下，本菌可在多種植物殘體上繁殖[34]。若除去土壤表層之有機質則可減輕本菌之爲害[17]，因此 Boyle（1961）[18]認爲本菌之菌核並未攜帶足夠的能量以產生代謝物質來殺死寄主細胞使其進入寄生生活，指出了腐生基質對本菌生長及致病能力之重要性。但是亦有報告指出添加堆肥[29]，燕麥桿[21]和苜蓿粉[26,27]可減低病害的發生，其原因可能是釋放氨氣和增加土壤中拮抗微生物的族群數量。筆者以盆栽方式測試八種有機質添加對病害之影響，顯示 1%（W/W）量苦茶渣、木屑、泥炭苔和蔗渣等在發病初期（接種第 34 天以前）病勢進展速度比對照組快，然而在發病後期（接種 55 天以後）則除了苦茶渣處理者外，其餘三者的植株被害度有減緩現象。在八種有機質添加物中，以幾丁質最能抑制病害的發生，其次是米糠和牛糞堆肥，其被害度均在 50% 以下，而對照組則高達 91.7%（圖一）。土壤中添加稻殼和木屑並不能降低太陽花的白絹病發病率，然而添加燕麥桿和蓖麻餅則可明顯降低病害的發生[21]，原因有二：1. 有機質在土壤中分解並釋放出水溶性（添加燕麥桿時）和醚溶性（添加蓖麻餅時）毒害物質，以抑制本菌的生長，2. 促進土壤中的微生物以拮抗本菌[21]。Linderman 氏[26,27]指出紫花苜蓿減輕白絹病菌爲害的作用有下列原因：1. 增加土壤中拮抗微生物之活力，2. 使本菌由抵抗性之菌核變成易受拮抗微生物侵襲之菌絲，3. 消耗菌核能源，使其抵抗力降低而使拮抗菌及腐生菌易於生長在菌核上，4. 阻止新菌核產生，以減少接種源潛勢。關於幾丁質降低病害的作用機制除增加土壤中細菌和放射線菌的量外，是否有抑制物質產生則有待進一步研究。

結　論

瞭解白絹病菌在土壤中的生態有助於防治工作的進行，利用菌核乾燥後再濕潤時會滲漏出胺基酸和糖類的特性，在種植前可將土壤翻耘曝曬後再加水灌溉，以降低接種源數量；或利用菌核於深土中不能發芽之特性，以深耕方式將土表之土壤及有機質深埋入土；另外可添加能提高土壤 pH 值之含氮化合物如碳酸銨、碳酸氫銨和尿素等及降低病害發生的有機質如幾丁質、米糠和牛糞堆肥以直接殺死菌核和間接促進土壤微生物而達到綜合防治之目的。關於防治百合白絹病病害發生最重要的一點是不要有違常規栽培，因爲植物生長勢衰弱時無法抗拒病原菌的侵害。綜合上述氮化合物和有機質對白絹病菌之影響可歸納下列幾點，以作爲本文之總結：1. 提高土壤 pH 值至 9.8 以上可直接對白絹病菌發生毒害，2. 氮化合物加入土壤中釋放出的氨氣會殺死本菌，3. 提高拮抗微生物之活力而抑制本菌的生長，4. 促進菌核之



圖一、有機質添加對百合白絹病病勢進展之影響

Fig 1. Effect of organic amendments on disease development of lily southern blight. Compost I = the high rotted cattle manure, Compost II = the half rotted waste of sawdust used for mushroom. All organic matters were amended at 1% (w/w) to soil, except chitin which was amended at 0.5% (w/w).

形成而進入休眠，5.促進菌核發芽以及土壤微生物之活力，使具抵抗力之菌核變成易受侵害之菌絲。

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ABSTRACT

Tu, C. C., Hsieh, T. F. and Tsai, W. H. 1991. **Effects of temperature, moisture and amendments on the occurrence of lily southern blight caused by *Sclerotium rolfsii* Sacc.** Plant Prot. Bull. 33:80-94. (Taiwan Agricultural Research Institute, Taichung, Taiwan, R.O.C.)

Lily southern blight was caused by *Sclerotium rolfsii* Sacc. When 5 dried sclerotia (Inoculum density about 2.6 sclerotia per 100 cm^3 of soil) were inoculated into soil around the bulb of lily within 1 cm, the yellowing symptom appeared within 2 weeks. Moreover, the disease severity increased gradually with increasing the number of sclerotia. On soil plate, the maximum sclerotial germination occurred at 20-28℃. The percentage of germination increased when the sclerotia were incubated under drying condition for 3 days at 20℃ and then remoistened and placed at 28℃. Consistently, the greater disease severity was obtained when the lily plants were transferred into the 28℃ condition after 1 week of incubation under 20℃. In general, the best solute water potential for sclerotial germination and mycelial growth was between -1 and -10 bars. However, with decreasing of solute water potential from -10 to -50 bars, the percentage of germination and growth rate decreased. Under the condition when tested

plants were transferred from 20 to 28℃ , the disease severity at both soil moisture treatments (15 and 30% MHC) was 0.81 aftet 4 weeks of inoculation, however, the disease development was faster at 15% than at 30% MHC. Among 21 tested chemical compounds that were amended to soil at 1% (W/W) rate, nitrogen compounds showed more inhibitory to the germination of sclerotia on soil plate than others. Sodium nitrite could completely inhibit the germination at 125 ppm nitrogen (N), ammonium bicarbonate at 250 ppm N, urea and ammonium carbonate at 500 ppm N. Ammonium acetate and ammonium citrate at 1000 ppm N also inhibited the germination completely. The percentage of sclerotial germination was decreased when 1% (W/W) chitin, chaff, bagasse, cattle manure or waste of sawdust compost used for mushroom growing was amended to soil. Moreover, the disease severity also was decreased after amendment with 0.5% (W/W) chitin, 1% (W/W) chaff or cattle manure. The effects of inorganic salts and organic matters on *Sclerotium rolfsii* and on the disease were discussed.

(Key words: lily, *Sclerotium rolfsii,* inoculum density, temperature, soil moisture, nitrogen compound, organic matter)

土壤病原生態與防治研討會專刊 95～102, 1991

應用太陽能及有機綠肥對番茄白絹病之防治效果

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摘 要

杜金池、程永雄、黃杉芭 1991 應用太陽能及有機綠肥對番茄白絹病之防治效果 植保會刊 33:95～102

爲有效防治番茄白絹病，於番茄種植前植畦覆蓋 0.25 mm PE 塑膠布處理，可提高土表層 5 公分處之溫度達 12℃，覆蓋塑膠布之處理最高地溫 51℃，最低地溫 27℃，調查期間 15 天內維持 40℃以上之時數達 119 小時之多，對照不覆蓋之最高地溫 39℃，最低地溫 23℃，未有 40℃以上之時數。種植前植畦覆蓋塑膠布處理，能有效控制番茄白絹病之發生，使土表及土表下 5 公分之白絹病菌核均未能存活，田間植株亦無白絹病之發生。植畦覆蓋塑膠布，並再添加有機綠肥，如苜蓿、太陽麻或玉米莖葉等，對番茄白絹病之防治效果比植畦覆蓋塑膠布單項處理爲優。

（關鍵字：番茄、白絹病菌、白絹病、太陽能、綠肥、防治）

緒 言

番茄白絹病（ southern blight ）爲嘉南平原番茄重要病害之一，近年來爲確保原料來源，常提早種植，又爲求提高單位面積產量，常施用超量有機堆肥，及前作收穫之廢棄物直接施於田間，因而白絹病之發生日趨嚴重。本病原菌（*Sclerotium rolfsii*）爲多犯性土壤傳播性病害，寄主範圍廣泛，在本省有 47 科， 129 種作物可被感染，以菌核爲其殘存及傳播之個體。因而其防治藉化學藥劑來消滅感染源，所花費不貲又難數效，休耕或輪作之防治效果亦不理想，且本病原菌有極多之生理小種，使抗病品種不易育成，故目前尚無理想之防治方法。

番茄白絹病爲土壤表生眞菌，其菌絲有向外密集生長之特性，因而應用太陽能消毒土壤，防治白絹病，即提高土表層溫度，改變土壤環境，造成不利病原體存活之條件，而殲滅菌絲及菌核，減少土壤中之感染源，達到防治本病害之發生，是爲本研究之目的。

植畦覆蓋透明塑膠布處理對土壤溫度之影響

利用透明塑膠布覆蓋植畦，增加土表溫度，土壤溫度係依全電子式自動多點溫度記錄器，調查記錄，處理期間土壤溫度之變化，並定期採集土表，土表下 5 公分及 10 公分之土樣收集菌核，以瓊脂平板培養基測定其發芽能力。

於番茄種植前，植畦覆蓋 0.25 mm 厚透明塑膠布處理，可提高土表層 5 公分之溫度 9～

12℃之多。覆蓋塑膠布處理最高地溫51℃，最低地溫27℃，兩期作之調查期間（15天及31天）內維持40℃以上之時數分別爲119小時及106小時，對照不覆蓋處理之最高地溫39℃，最低地溫23℃，40℃以上之時數0小時（表一、二）。

一日中之土壤溫度受到氣溫、降雨及日射量之影響，平常以下午1時～3時間之地溫最高。

植畦覆蓋塑膠布處理對土中白絹病菌菌核存活之影響

在台南區農改場農場設立白絹病試驗田乙處（經人工接種），砂質壤土，PH 6.7，有機質1.16%，氯化鉀369 kg/ha，磷矽630 kg/ha，種植前一個月進行田間處理，處理方法爲：植畦覆蓋塑膠布、植畦覆蓋塑膠布並添加乾或鮮太陽麻，或乾、鮮玉米莖葉，另以植畦不覆蓋施用標準量堆肥1噸/0.1公頃，或超量堆肥2噸/0.1公頃，爲對照等七處理，四重複，採完全逢機區集列，小區面積16.8平方公尺。分別於處理期間及植株生長期間調查，土表、土表下5公分及土表下10公分之土壤溫度，番茄植株、分地際基部、分枝莖部及果實等罹患白絹病情形，及調查土中菌核之存活率以及收穫時記錄處理區番茄收量。

採取土表及土表下5公分與10公分之土壤，依篩網傾注法收集菌核，以瓊脂平板培養基測定其存活。發現植畦覆蓋處理能有效降低病原菌菌核存活之能力。土表及土表下5公分處均未發現有存活之菌核，而植畦覆蓋塑膠布並再添加有機綠肥（太陽麻、玉米莖葉）對番茄白絹病菌核之殺滅效果比植畦覆蓋塑膠布單項處理者爲優（表三）。

植畦覆蓋透明塑膠布處理對番茄白絹病之防治結果

植畦覆蓋透明塑膠布處理能有效抑制番茄白絹病之發生。1983年度調查結果顯示，植畦覆蓋塑膠布處理，番茄僅在地際莖部感染白

表一、植畦覆蓋塑膠布對土壤溫度之影響（1983）[1)]

Table 1. Effect of mulching of planting row with plastic sheet on soil temperature in 1983

植畦處理 Treatment of planting row		土壤溫度（℃）soil temperature 最高土溫 maximum temp.（℃）	40℃以上時數 hours of temp. over 40℃ (hr.)	45℃以上時數 hours of temp. over 45℃ (hr.)
覆蓋塑膠布處理 mulching PE sheet				
土表	soil level	54	279	187
土表下5公分	5 cm in depth	48	106	22
土表下10公分	10 cm in depth	43	18	0
土表下15公分	15 cm in depth	41	3	0
對照無覆蓋 without mulching PE sheet				
土表	soil level	49	22	7
土表下5公分	5 cm in depth	39	0	0
土表下10公分	10 cm in depth	36	0	0
土表下15公分	15 cm in depth	34	0	0

1) 調查期間：1983年8月16日～9月16日
Period of Investigation: Aug. 16~Sept. 16, 1983

表二、植畦覆蓋塑膠布對土壤溫度之影響（1984）[1)]

Table 2. Effect of mulching of planting row with plastic sheet on soil temperature in 1984

植畦處理 Treatment of planting row		土壤溫度（℃）soil temperature 最高土溫 max. temp. (℃)	最低土溫 min. temp. (℃)	40℃以上時數 hrs. of temp. over 40℃ (hr.)	45℃以上時數 hrs. of temp. over 45℃ (hr.)	50℃以上時數 hrs. of temp. over 50℃ (hr.)
覆蓋塑膠布處理 mulching PE sheet						
土表	soil level	54	27	124	28	17
土表下5公分	5 cm in depth	51	27	119	29	18
土表下10公分	10 cm in depth	46	28	73	8	0
對照無覆蓋 without mulching PE sheet						
土表	soil level	43	23	13	3	0
土表下5公分	5 cm in depth	39	23	0	0	0
土表下10公分	10 cm in depth	35	24	0	0	0

1) 調查期間：1984年9月15日～9月30日
Period of Investigation: sept. 15~Sept. 30, 1983

表三、植畦覆蓋塑膠布對白絹病菌核存活之影響[1)]

Table 3. Effect of mulching of planting row with plastic sheet on survival of sclerotia

植畦處理 Treatment of planting row	菌核發芽率（%）Germination of Sclerotia 土表 soil level	土表下5公分 5 cm in depth	土表下10公分 10 cm in depth	土表下15公分 15 cm in depth
覆蓋塑膠布處理 mulching PE sheet	0	0	1.3	2.6
植畦添加乾太陽麻 amended with dry sun hemp	0	0	0	0
植畦添加鮮太陽麻 amended with fresh sun hemp	0	0	0	0
植畦添加乾玉米莖葉 amended with dry corn leaves	0	0	0	1.6
植畦添加鮮玉米莖葉 amended with fresh corn leaves	0	0	0	0
植畦不覆蓋 without mulching PE sheet				
施用超量堆肥2噸/10公畝 fertilized exceed amount of compost	47.8	28.5	11.1	14.0
施用標準量堆肥1噸/10公畝 fertilized standard amount of compost	14.5	15.8	11.7	13.4

1) 1984年9月15日處理，10月1日調查
Treated on sept. 15, Investigation on Oct. 1, 1984

絹病 0.6%，而分枝莖部、果實等均未被感染。覆蓋塑膠布並添加苜蓿或太陽麻處理，番茄植株未見白絹病之發生，而對照無處理植株地際莖部感染白絹病爲 1.9%，分枝莖部感染株達 9.7%，果實罹病率 0.6%（表四）。1984 年度之調查結果，植畦添加太陽麻或玉米莖葉並覆蓋塑膠布處理，番茄植株均未見白絹病之發生，對照不覆蓋，施用超量堆肥 2 噸 /0.1 公頃，番茄植株之地際部發生白絹病達 10.6%，分枝莖部 2.1%，果實 0.6%，另一對照區植畦不覆蓋施用標準量堆肥 1 噸 /0.1 公頃處理，番茄地際莖部白絹病發生 6.9%，分枝莖部 0.7%，果實 0.4%（表五）。

植畦覆蓋塑膠布處理對番茄生產之影響

植畦覆蓋處理能顯著地增加番茄單位面積產量。1983 年度調查結果，覆蓋處理區每公頃番茄產量約在 145,900 ～ 151,000 公斤之間，對照無處理區每公頃番茄產量爲 127,000 公斤。1984 年度調查結果，覆蓋處理每公頃產量 86,000 ～ 78,600 公斤，對照不覆蓋施用標準堆肥者每公頃 68,000 公斤（表六、七）。

植畦覆蓋塑膠布對番茄產量增加原因，除未被白絹病之侵害而增加外，可能因覆蓋處理而改變土壤性質，促進番茄生育所致。

結　論

番茄白絹病（*Sclerotium rolfsii*）爲多犯性土壤傳播病原菌，以菌核爲主要殘存及傳播個體，好氣性菌絲在土表 0.5 吋以下生長即受影響，故常於土表或地際部之作物根部，莖部之寄主組織發現白色菌絲體。

病原菌絲之發育適溫爲 25 ～ 30 ℃，40 ℃及 10 ℃爲其上下限，40 ℃不形成菌核，菌核之發芽最適溫度爲 31 ℃，37 ℃時菌核不能發芽，菌核在 50 ℃之熱水中可以存活 90 ～ 105 分鐘。基於本病原菌之特性，探討太陽能對白絹病菌之致死效果，試驗結果發現植株畦覆蓋透明塑膠在（0.25 mm 厚）可提高土表層 5 公分處之土壤溫度達 12 ℃之多，而最高溫度達到 51 ℃。在 1984 年 9 月 15 日至 9 月 30 日調查

表四、植畦覆蓋處理對田間蕃茄白絹病發生之影響（1983）

Table 4. Effect of mulching of planting row with plastic sheet on the outbreak of southern blight of tomato in 1983

植畦處理 Treatment of planting row	白絹病發生百分率（%）percent of southern blight			
	地際莖部 stem on the ground		分枝莖部 branch of stem	果實 fruit
	移植後 30 天 30 days after transplanting	移植後 90 天 90 days after transplanting		
植畦覆蓋塑膠布 Planting row mulching PE sheet	0	0.6	0	0
植畦添加苜蓿，覆蓋塑膠布 planting row amended with alfalfa and mulched with PE sheet	0	0	0	0
植畦添加太陽麻，覆蓋塑膠布 planting row amended with sun hemp and mulched with PE sheet	0	0	0	0
對照無處理 without any treatments	0.6	1.3	9.8	0.6

表五、植畦覆蓋處理對田間蕃茄白絹病發生之影響（1984）[1)]

Table 5. Effect of mulching of planting row with plastic sheet on the outbreak of southern blight of tomato in 1984

植畦處理 Treatment of planting row	白絹病發生百分率（%） percent of southern blight		
	地際莖部[2)] stem on the ground	分枝莖部[3)] branch of stem	果實 fruit
覆蓋塑膠布處理 mulching PE sheet	0	0	0
植畦添加乾太陽麻 amended with dry sun hemp	0	0	0
植畦添加鮮太陽麻 amended with fresh sun hemp	0	0	0
植畦添加乾玉米莖葉 amended with dry corn leaves	0	0	0
植畦添加鮮玉米莖葉 amended with fresh corn leaves	0	0	0
植畦不覆蓋 without mulching PE sheet			
施用超量堆肥 2 噸/10 公畝 fertilized exceed amount of compost	10.6	2.1	0.6
施用標準量堆肥 1 噸/10 公畝 fertilized standard amount of compost	6.9	0.7	0.4

1) 表列數字爲四重覆平均值 The number is an average of 4 replicates
2) 移植後 80 天調查結果 The result at 80 days after transplanting
3) 移植後 95 天調查結果 The result at 95 days after transplanting

期間 15 天內可維持 40℃以上之時數達 119 小時，45℃以上持續 29 小時而對照不覆蓋爲 0 小時。種植前植畦覆蓋塑膠布處理所提高之土壤溫度恰可消滅土表層之菌核，而達到消滅或減少土中有效的感染源。又因植畦覆蓋塑膠布，減少分枝莖部與果實接觸土壤之機會而減少被白絹病菌之感染。

植畦添加苜蓿、太陽麻、玉米莖葉等有機綠肥並覆蓋塑膠在處理，亦能有效控制番茄白絹病之發生，且其效果比種植前植畦覆蓋塑膠布單項處理爲優，即種植前植畦覆蓋塑膠布已有防治效果，添加有機綠肥更增加抑制效果，是因有機綠肥在醱酵分解過程中產生之能量有助土壤溫度之提高，以及其他有益微生物之活躍，消滅土表殘存之菌核，而達到降低有效之感染源。

田間覆蓋塑膠布處理，除防治白絹病之發生爲害外，還可防止植畦中肥分之流失，雜草之滋生，土表保持鬆軟及濕度而促進番茄之生育等優點。

嘉南地區爲亞熱帶，在秋作期間仍有豐富之陽光可利用，應用太陽能來防治土壤傳播性病害，尤其是白絹病，更能表現其防治效果，既經濟、節省資源，又方便無公害等利益，是值得研究且推廣應用。

表六、植畦覆蓋處理對蕃茄產量之影響（1983）[1)]

Table 6. Effect of mulching of planting row with plastic sheet on product of tomato in 1983

植畦處理 Treatment of planting row	產量 (product) kg/ha
植畦覆蓋塑膠布 planting row mulching PE sheet	145,940 ab[2)]
植畦添加苜蓿，覆蓋塑膠布 planting row amended with alfalfa and mulched with PE sheet	151,024 a
植畦添加太陽麻，覆蓋塑膠布 planting row amended with sun hemp and mulched with PE sheet	149,104 a
對照無處理 without any treatments	127,454 b

1) 表列數字爲四重覆平均值，供試品種盛岡7號。
The number is an average of 4 replicates

2) 表列英文字母相同者係依 Duncan's 多變域法測得 P = 0.05 不顯著。
Column followed by the same letter are not significantly different at the 0.05 level by Duncan's multiple range test

表七、植畦覆蓋處理對蕃茄產量之影響（1984）[1)]

Table 7. Effect of mulching of planting row with plastic sheet on product of tomato in 1984

植畦處理 Treatment of planting row	產量 (product) kg/ha
覆蓋塑膠布處理 mulching PE sheet	84,239 a
植畦添加乾太陽麻 amended with dry sun hemp	84,396 a
植畦添加鮮太陽麻 amended with fresh sun hemp	86,232 a
植畦添加乾玉米莖葉 amended with dry corn leaves	78,602 a
植畦添加鮮玉米莖葉 amended with fresh corn leaves	82,521 a
植畦不覆蓋 without mulching PE sheet	
施用超量堆肥 2 噸 /10 公畝 fertilized exceed amount of compost	79,071 a
施用標準量堆肥 1 噸 /10 公畝 fertilized standard amount of compost	68,029 a

1) 表列數字爲四重覆平均值，供試品種臺南選2號。
The number is an average of 4 replicates

2) 表列英文字母相同者係依 Duncan's 多變域法測得 P = 0.05 不顯著。
Column followed by the same letter are not significantly different at the 0.05 level by Duncan's multiple range test

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ABSTRACT

Tu, C. C[1]., Cheny, Y. H[1]. and Hwang, S. C[2]. 1991. Effects of solar energy and green manures on the control of southern blight of tomato. Plant Prot. Bull. 33:95-102. (1. Taiwan Agricultural Research Institute, Taichung, Taiwan, R.O.C. and TARI Chiayi Agricultural Experiment Station, Chia-yi, Taiwan, respectively, 2. Tainan District Agricultural Improvement Station, Tainan, Taiwan, R.O.C.)

For control of southern blight of tomato caused by *Sclerotium rolfsii*, mulching of planting row with transparent plastic sheet before planting was studied. The temperature under soil surface 5cm in depth could increase 12℃ after mulching and number of hour for soil temperature reached at or over 40℃ was 119 during the 15-day test

period, while the soil temperature of control plot without mulching never reached 40 ℃. The highest and the lowest temperature of soil were 51℃ and 27℃ for the plot with mulching treatment, respectively, and were 39℃ and 23℃ for the control plot without mulching treatment, respectively. The mulching treastment was effective in controlling southern blight of tomato. The sclerotia of *S. rolfsii* could not survive in the soil surface and under soil surface 5 cm in depth. However, the planting row amended with green manure and mulched with plastic sheet was better for the disease control than the mulching treatment alone.

(Key words: *Sclerotium rolfsii*, tomato, southern blight, solar energy, green manure, control)

土壤病原生態與防治研討會專刊 103～112, 1991

Phytophthora citrophthora 及 *P. nicotianae* 引起的番荔枝果實疫病

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摘　要

黃穗昌、呂麗華、李惠鈴 1991 ***Phytophthora citrophthora*** 及 ***P. nicotianae*** 引起的番荔枝果實疫病　植保會刊 33:103～112

由 *Phytophthora citrophthora* 及 *P. nicotianae* 引起的番荔枝果實疫病分別於 1990 年 1 月及 10 月間首先在台東被發現，果實被害時開始出現紫黑或褐黑斑塊，被害果肉組織變成淡褐～黑褐色，5 至 6 天後全果變黑並木乃伊化。*P. citrophthora* 爲 A^1 配對型，最低、最適、最高生長溫度各爲 10、26 及 33℃，胞囊卵形或檸檬形，非脫落性，平均 45.5 × 30 μm，具明顯乳頭狀突起，但經常變形，游走子感染無傷口果實的最低濃度約 3.3～8.8 × 10^2 spores/0.2 ml。由其引起的黑變病，目前僅零星發生於 10 月至翌年 1 月間。*P. nicotianae* 胞囊寬卵形，平均 37 × 30 μm，具明顯乳頭狀突起，菌絲最低生長溫度約 10℃，最高溫度超過 37℃，其於田間發生比例低於 *P. citrophthora*。以 58% 鋅錳滅達樂可濕性粉劑 400 倍或 76.5% 銅滅達樂可濕性粉劑 1,000 倍處理果實，可有效防止 *P. citrophthora* 的感染，但病斑出現後，所有供試藥劑均無法抑制病斑擴展。

（關鍵字：番荔枝、果實病害、疫病菌）

緒　言

番荔枝（*Annona squamosa* L.）屬番荔枝科（Annonaceae），英名 sweet sop 或 sugar apple，俗稱番荔枝，爲本省近十餘年來新興的經濟果樹，目前全省栽培面積逾 5,000 公頃，而僅台東地區即近 3,500 公頃，已成爲該地區最重要的經濟果樹[2,12]。有關番荔枝果實病害，以往研究不多，報告散見於澳洲及印度[8,9,10,13,16,18]。而可以造成果實黑變的病原經記錄者有 *Phomopsis anonacearum* Bondartzeva-Monteverde、*Phytophthora palmivora* Butler、*Botryodiplodia theobromae* Pat.、*Glomerella cingulata* (Stonem.) Spauld. & Schrenk var. *minor* Wr.[8,9,11,12,17]。台東地區栽種的番荔枝近幾年來果實黑變的現象日益普遍，經筆者等近一年來全面調查，已初步證實數種病原眞菌可導致番荔枝果實黑變[4]，其中一種經鑑定爲 *Phytophthora citrophthora*（Smith & Smith）Leonian，另一種則爲 *P. nicotianae* Breda de Haan（Syn. *P. parasitica* Dastur），此二種引起的黑變病初步命名爲果實疫病，本文報告本病病徵、發生季節、病菌特性及其防治。

材料與方法

病原菌來源

於1990年1月間，1990年7、8、10月間，分赴台東地區各處番荔枝園採集全部或局部變黑果實，攜回室內記錄各樣品的黑變情形後，以75%酒精擦拭果實表面，剖開果實，切取鱗目或果肉褐變前緣小塊組織，移入水瓊脂平板上，於室溫下經3～4天，待菌絲長出後，切取菌絲頂端移入PDA斜面上培養，原來的水瓊脂平板則繼續保留，經4～5天分別鏡檢PDA斜面上及水瓊脂平板上的菌體，由菌絲形態及在水瓊脂上產生胞囊的情形，選出屬於*Phytophthora*的菌株10個，這些菌株經移入含5% V-8果菜汁、0.02% $CaCO_3$、50 ppm mycostatin、100 ppm ampicillin、10 ppm PCNB（pentachloronitrobenzene）及2% Bacto agar的選擇性培養基平板上純化培養後，均移至10% V-8洋菜培養基斜面上保存備用[6]，並分別編列代號爲PA1～10，其中PA1～9等9個菌株後來經鑑定證實爲*P. citrophthora*（Smith & Smith）Leonian，PA10則爲*P. nicotianae* Breda de Haan（*P. parasitica* Dastur）。本研究中供試的其它*Phytophthora*菌株—*P. cinnamomi* PC97、CV64F，*P. parasitica* P991、P731, *P. citrophthora* PCC 9～10（分自柑桔）由安寶貞博士提供，*P. palmivora* PP1則由筆者分自嘉德利亞蘭罹病葉片。

病原菌鑑定

將供試的*Phytophthora*菌株PA1、PA2、PA3、PC97、PCC9-10及P991培養於20% V-8洋菜培養基平板，28℃下三天後，以打孔器打下直徑0.5 cm的新鮮菌絲塊，置於20% V-8洋菜培養基平板上，分別放入8、10、12、16、20、24、26、28、30、32、33、34、37℃的定溫培養箱，每24小時測量各菌株菌絲生長直徑並觀察菌落形態，至第7天爲止。促使胞囊（sporangia）產生時，則將菌株培養於10% V-8洋菜培養基平板上，長滿後切成一平方公分以下的小塊，分置於培養皿內，倒入無菌水浸洗培養基的養分，連續換洗三次，每次10～20分鐘，最後再倒入少許無菌水，使水面剛好與菌絲塊高度平，放於28℃定溫箱中照光1～2天。欲使胞囊釋放游走子時，則將長有胞囊的菌絲塊放入15℃的定溫箱中30分鐘，取出後置於室溫（26～28℃）中15～30分鐘，將菌絲塊切成薄片後，於光學顯微鏡下觀察菌絲、厚膜胞子（chlamydospores）、胞柄（sporangiophores）、胞囊及游走子（zoospores）的形態及大小[1,15]。鑑別其有性繁殖特性時，則將PA1、PA2及PA3菌株在10% V-8培養基上培養6天，而後以polycarbonate membrane法，與配對標準菌株P991(A^1)、P731(A^2)或PC97(A^1)、CV64F(A^2)配對，在24℃無光照下培養6天後，鏡檢有性器官產生情形[6,7,16]。

接種試驗

以菌絲塊接種番荔枝無傷口果實及葉片時，供試菌株均培養於20% V-8培養基上，經2～3天後打取直徑0.5 cm的菌絲塊，貼置於經75%酒精表面消毒的果實、葉背或葉面，覆上濕棉球，並以膠帶固定，封於塑膠袋中；如行果實傷口接種，則將果實挖－5×5×4 mm洞，塞入同等大小的菌絲塊，將挖出的組織塊填回，放入含濕棉球的塑膠袋中，定時比較各菌株致病的情形。以游走子接種時，則如上述方法製備PA1濃厚游走子懸浮液（6.5×10^4 spores/ml），取0.05 ml分別滴於番荔枝葉面及葉背，或以小型噴霧器噴於葉背、葉面，放於含濕棉球的塑膠袋中；接種果實時，則將PA1、PA2、PA3的濃厚游走子懸浮液（1.1～3.5×10^5 spores/ml），以無菌水做5倍系列稀釋，將不同濃度的游走子懸浮液0.2 ml分別滴於番荔枝果實鱗溝，去柄及不去柄果蒂處，封於含濕棉球的塑膠袋中，比較各接種處理發病情形。

防治試驗

選擇54種殺菌劑—70%普拔克（Previcur-N）S、25%撲克拉（Sportak）EC、25%依得利（Terrazole）EC、50%大克爛（Dicloran）WP、80%免得爛（Mitram）WP、40%亞納銅（Yonepon）WP、56%氧化亞銅（Cuprous oxide）、35%護粒丹（Hinodan）WP、58%鋅錳滅達樂（Ridomil-MZ）WP、77.5%嘉賜銅（Kasuran）WP、50%益發靈（Euparen）WP、25%山陽銅（Sanyol）EC、68.5%鋅銅四氯

丹（Zincofol）WP、65%保粒四氯丹（SN-72802）WP、39%硫酸快得寧（Basic copper sulfate + Oxine-copper）WP、40%銅快得寧（Kinset）WP、63%銅鋅錳乃浦（Mancozeb-Cu）WP、78%鋅錳波爾多（Bordeaux-MZ）WP、80%銅合浦（Macuprax）WP、82%銅錳乃浦（Comac-bordeaux M）WP、77%氫氧化銅（Kocide）WP、72%鋅錳克絕（Curzate-M）WP、50%脫克松（Rizolex）WP、50%撲滅寧（Sumilex）WP、3%殺紋寧（Tachigaren）S、16.5%滅紋（Mon）EC、70%甲基鋅乃浦（Antracol）WP、75%滅普寧（Basitac）WP、70%免得克寧（Ronilan-M）WP、50%依普同（Rovral）WP、50%免克寧（Ronilan）、25%普克利（Tilt）EC、50%福多寧（Mocut）WP、50%蓋克爛（Dicap）WP、70%甲基多保淨（Topsin-M）WP、50%免賴地（Benlate-T）WP、40%快得寧（Quinolate）WP、75%快得保淨（Topsin-M Do）WP、76.5%銅滅達樂（Ridomil-Cupnait）WP、40%亞賜圃（Fuji-One）EC、50%撲克拉錳（Sporgon）WP、25%賓克隆（Monceren）WP、60%得滅寧混合（Sumilex-D）WP、80%福賽得（Aliette）WP、11.76%芬瑞莫（Rubigan）EC、40%腐絕（Mertect）WP、21.2%依滅列（Fungaflor）、12%邁克尼（Systhane）EC、18%貝芬寧混合（Vereor multi）FP、20%得滅多（Denmert）WP、93%硫免賴得（Benlate-S）WP、25%克熱淨（Befran）S、50%貝芬同（Rovral-M）WP及23.7%依普同（Rovral）FP，各藥劑均以無菌水稀釋成慣用的濃度，將直徑0.9 cm的濾紙圓片（Schleicher & Schuell No.321261）浸入各藥劑中，經10分鐘後取出，於無菌操作台中風乾，再將各濾紙圓片均勻貼置於PDA平板上，每平板置不同處理的圓片3片，及僅浸無菌水對照者1片，隨即於平板中央貼置一塊直徑0.5 cm的PA1、PA2或PA3菌株菌絲塊，放入28℃中，經3～4天當菌絲長至不處理對照圓片邊緣時，調查各處理造成的菌絲生長抑制長度，由此選出抑菌效果較佳的藥劑數種，連同數種慣用於疫病防治的藥劑共8種，直接於番荔枝果實上測試各藥劑對黑變病的防治效果，測試時先將去果柄的果實浸入各藥劑稀釋液中10分鐘，撈起後風乾，24小時後將PA1的濃厚游走子懸浮液（7.8×10^4 spores/ml）0.1 ml滴於果蒂處，密封於高濕塑膠袋中，經48小時後每天調查果實黑變程度；另一組則先將游走子懸浮液滴於未經藥劑處理的果實果蒂處，經48小時果蒂處已開始黑變時，將各藥劑稀釋液分別均勻噴灑於發病果實，每24小時調查各處理果實黑變程度。黑變程度分成4級，未發病者爲0，黑變面積佔全果1/4以下者爲1，1/4～2/4者爲2，2/4～3/4者爲3，3/4以上者爲4，由此換算成各處理的罹病度。

發生調查

於番荔枝夏、冬季盛果期分赴台東各地果園採集局部或全部黑變的果實，如上述方法分離病菌，經接種確定其病原性後，依病菌各項特徵鑑別其種類，同時比較各病菌造成病徵間的差異，及各病菌出現的頻度。

結　果

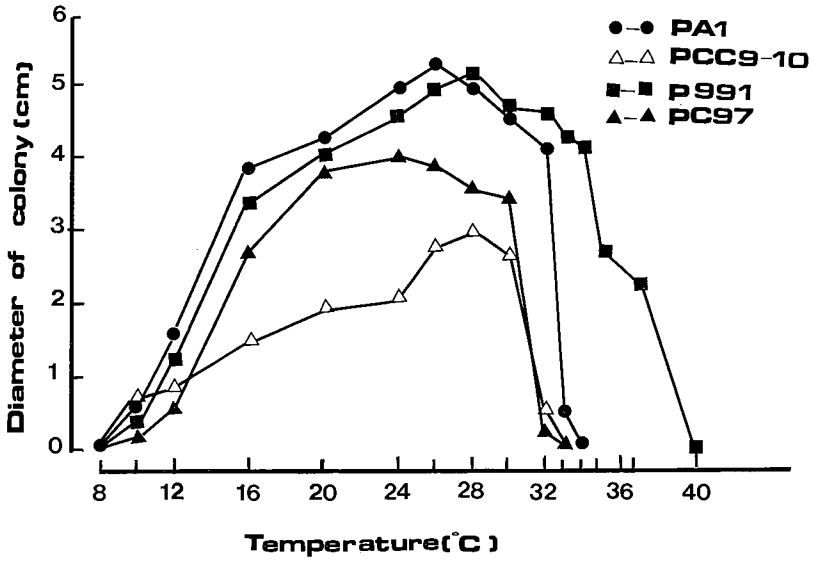
病菌形態與特性

由番荔枝黑變果分離到的10個 *Phytophthora* 菌株，有9個菌株（PA1～9）各項形態及特性均類似，其於V-8洋菜培養基上菌落呈細緻放射狀，氣生菌絲稀少，菌絲寬4.5～7.5 μm，胞柄不規則分枝，寬1.8～2.8 μm，分叉處及近胞囊處常見膨大。在V-8洋菜培養基上，除PA4、PA6及PA8產生胞囊較稀少（60倍下每視野10餘個）外，其他菌株均可產生不少胞囊（每視野100～200個），淹水後產生更多，胞囊卵圓形或檸檬形，通常頂生，偶爾間生，大小隨菌株不同而略有差異，以代表菌株PA1爲例，約55～35 × 35～22.5 μm，平均45.5 × 30 μm，乳頭狀突起明顯（圖一），在V-8培養基上偶爾出現變形胞囊，淹水過多時，則經常可見長棍棒形、豆形，或具雙乳頭突起的變形胞囊。胞囊非脫落性，經低溫處理後容易釋放出游走子，每一胞囊平均約可放出25個游走子，游走子具二鞭毛，於室溫下經

15～30分鐘後即成靜止子（cysts），靜止子球形，直徑平均約9.6 μm，胞囊在28℃的恒溫中可直接發芽，有時並再長出較小型胞囊。厚膜胞子經常可見，球形，直徑22.5～32.5 μm，平均25.6 μm。PA1、PA2或PA3在V-8培養基上不會產生有性繁殖器官，與 *P. cinnamomi* 或 *P. parasitica* 之 A^2 型菌株配對後均可誘導後二者產生卵胞子（oospores），顯示該三菌株均屬於 A^1 配對型，但其於配對後產生的有性繁殖器官卻極稀少，僅發現的一個藏卵器（oogonium）淡黃色，直徑20.3 μm，藏精器（antheridium）底著，近球形，直徑約12 μm。該類菌株最適生長溫度約26℃，32℃下生長不差，10℃及33℃下生長極爲緩慢，適溫下每天可長15.8～17.4 mm，與分自柑桔的 *P. citrophthora* 相較，前者生長速度較快，且較耐高溫（圖二）。綜上結果，顯示PA1～9等9菌株應均屬於 *P. citrophthora*（Smith & Smith）Leonian。而另一菌株P10，其菌落在V-8培養基上呈不均勻的絨毛狀，氣生菌絲豐富，形成的胞囊寬卵形，40～32.5 × 22.5～32.5 μm，平均約37 × 30 μm，在35℃下生長良好，37℃下亦能生長，經鑑定爲 *P. nicotianae* Breda de Haan（Syn. *P. parasitica* Dastur）[13,15,21,22]。

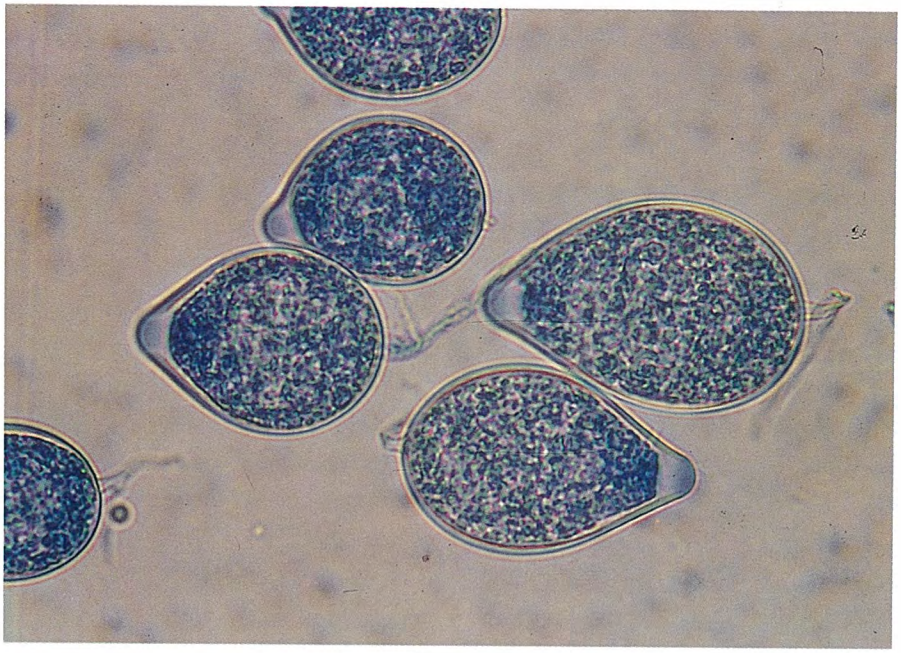
接種試驗

以 *P. citrophthora.* PA1.、*P. citrophthora* PCC 9-10、*P. parasitica* P 991、*P. cinnamomi* PC97及 *P. palmivora* PP1新鮮菌絲塊接種番荔枝葉背、受傷及未受傷果實均可造成相似的病徵，在葉片上病徵通常於3天後出現，開始爲黑褐色水浸狀斑，逐日擴大，濕度低時患部乾枯成褐～暗褐色。在果實上病斑通常於接種後2～3天出現，傷口接種較無傷口接種快，開始時爲紫黑或褐黑色斑塊，病部與健部界線不明顯，剖開果實通常可見果肉病部前緣組織爲水浸狀淡褐色，後來變成黑褐色（圖三），但也有些樣品的病部前緣爲暗褐色，發病果實通常5～6天後整粒變黑，後來木乃伊化（mummified），表面則常滋生白色腐生眞菌，軟熟的果肉組織則不會被感染變色。在供試的5個菌株中以PA1及P991致病力最强，PCC9-10、PC97及PP1則略差、接種葉面時一般不易發病，其中以PA1的致病力最强，而PC97



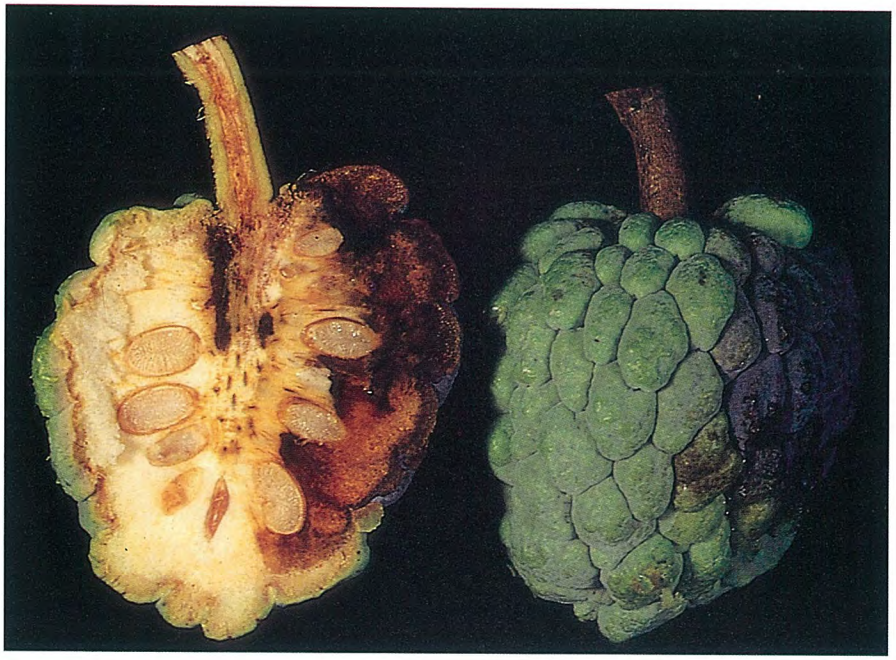
圖二、溫度對不同疫病菌株菌絲生長的影響

Fig 2. Effect of temperature on mycelial growth of different *Phytophthora* species. PA1, *P. citrophthora* from sugar apple; PCC9-10, *P. citrophthora* from citrus; P991, *P. parasitica* from citrus; PC 97, *P. cinnamomi* from camellia. Data were recorded at 72 hr after inoculation on V-8 agar media.



圖一、*Phytophthora citrophthora* 之胞囊

Fig 1. Sporangia of *Phytophthora citrophthora*



圖三、*P. citrophthora* 引起之番荔枝果實疫病病徵

Fig 3. Symptoms of phytophthora fruit rot of sugar apple caused by *P. citrophthora*

最差（表一）。以PA1的游走子接種於葉背時，不論是噴霧或點滴，病斑通常於16～24小時後出現，葉面接種則幾不發病。以PA1、PA2、PA3的游走子接種於去柄果蒂、不去柄果蒂及鱗溝時，去柄果蒂處最易發病，即使胞子濃度在7～15 spores/0.2 ml間，也均可在接種後3～5天出現病徵，7～10天後使全果變黑；自鱗溝處發病的速度較慢，所需最低發病胞子濃度亦較高，通常3.3～8.8 × 10^2 spores/0.2 ml才會致病，病徵於2～3天後出現，5～6天後使全果變黑；自不摘柄的果蒂處接種則最不易發病，其發病所需最低胞子濃度約4.4～14.1 × 10^3 spores/0.2 ml間。

防治試驗

在PDA培養基上，供試的54種殺菌劑中大都對PA1、PA2及PA3菌絲生長沒有抑制作用，或抑制效果不佳，但其中銅滅達樂1,000倍、銅快得寧500倍、硫酸快得寧500倍、鋅錳滅達樂400倍、氫氧化銅400倍及銅鋅錳乃浦500倍卻表現明顯的抑制效果，其對以上三菌株的抑制長度平均依序爲14.0、13.7、13.4、13.3、9.4、9.2 mm。在果實上的試驗，預防病菌侵入感染以58%鋅錳滅達樂WP 400倍效果最優，其次爲76.5%銅滅達樂WP 1,000倍及80%福賽得WP 500倍，當不處理對照果實的罹病度爲98.5%時，經上三種藥劑處理後的果實罹病度依序爲9.8%、39.3%及75.0%（表二），其它藥劑處理與對照組差異不顯著，其中依得利乳劑處理後會導致果實表皮變黑。而如果實發病後再噴灑殺菌劑，則各藥劑均無法顯著抑制病斑擴展。

發生調查

於1990年1、7、8、10月間共計採集調查4次，除1月間局部採集外，其它月份均赴台東番荔枝栽培區全面逢機採集局部、大部或全部變黑的果實，結果自這些可疑病果上有些分不到菌類，有些分到腐生菌，但也分到6類可以導致果實黑變的病原眞菌，分別爲 *Botryodiplodia theobromae*、*Colletotrichum* sp.、*Phomopsis* sp.、*Phoma* sp.、*P. citrophthora* 及 *P. nicotianae* [4]。*P. citrophthora*主要出現於1月及10月，但出現頻度不高，於10月間僅佔分出病原菌樣品的6.8%，7、8月間則未曾發現，*P. nicotianae*則僅於10月間自一病變樣品中被分出，出現頻度僅1.1%（表三）。這二種病原菌通常分自果皮有大型紫黑或褐黑色斑塊，果肉組織並變成黑褐色的樣品。

討　論

可以造成番荔枝果實黑變的病原眞菌，據國外報告計有4種[12,14,17]，本研究及相關的其它研究則發現6種可以導致果實黑變的病菌，

表一、不同疫病菌菌株對番荔枝果實與葉片之致病力

Table 1. Pathogenicity of *Phytophthora* species to fruits and leaves of *Annona squamosa*[1)]

Isolate	Disease incidence when inoculated on[2)]			
	Lower epidermis	Upper epidermis	Wound fruit	Non-wound fruit
P. citrophthora (PA1)	9/10	5/10	10/10 (10/10)	10/10 (10/10)
P. citrophthora (PCC9-10)	6/10	2/10	10/10 (6/10)	10/10 (4/10)
P. parasitica (P991)	10/10	3/10	10/10 (10/10)	10/10 (10/10)
P. cinnamomi (PC97)	9/10	0/10	10/10 (5/10)	10/10 (5/10)
P. palmivora (PP1)	10/10	2/10	10/10 (6/10)	10/10 (5/10)

1) Inoculations were made with mycelial agar blocks, 10 replications for each inoculation. Data were recorded at 5 days after inoculation.

2) Data represent ratios of diseased fruits or leaves to inoculated fruits or leaves and ratios of completely blackened fruits to inoculated fruit (parentheses).

表二、不同藥劑處理後番荔枝 *Phytophthora* 果實疫病罹病度

Table 2. Disease severity of Phytophthora fruit rot of *Annona squamosa* caused by *P. citrophthora* after treatments with several fungicides[1)]

Fungicide	Disease incidence (%)[2)]		
	3 days after inoculation	4 days after inoculation	5 days after inoculation
40% Previcur-N S (1.3 ml/l)	23.5 c	51.8 b	92.3 d
58% Ridomil-MZ WP (2.5 g/l)	1.5 a	6.3 a	9.8 a
80% Aliette WP (2 g/l)	9.8 b	42.3 b	75.0 c
76.5% Ridomil-Cupnait WP (1 g/l)	1.5 a	20.5 a	39.3 b
25% Terrazole EC (0.4 ml/l)	23.5 c	76.3 c	95.3 d
40% Kinset WP (2 g/l)	31.3 e	82.8 c	100.0 d
80% Mancozeb WP (2.5 g/l)	26.5 cde	78.3 c	100.0 d
40% Mertect WP (0.5 g/l)	25.0 cd	86.3 c	100.0 d
Nontreated control	29.5 de	75.0 c	98.5 d

1) Fruits removed of pedicels were dipped in different fungicides for 10 minutes, and 24 hr later, inoculated with zoospores of *P. citrophthora* PA1 at scars.

2) Numbers are means of four replicates, 8 fruits per replicate. Any two means followed by the same letter are not significantly different at $p = 0.05$ according to DMRT.

表三、*Phytophthora citrophthora* 、*P. nicotianae* 及其它果實黑變病菌出現頻度比較

Table 3. Frequency of *P. citrophthora* and *P. nicotianae* isolated from diseased black fruits compared to that of other pathogenic fungi[1)]

	Frequency of isolation (%) in			
	Jan.	July	Aug.	Oct.
P. citrophthora	16.7	—	—	6.8
P. nicotianae	—	—	—	1.1
Botryodiplodia theobromae	83.3	81.3	79.1	14.8
Colletotrichum sp.	—	14.6	16.3	42.0
Phomopsis sp.	—	2.1	4.6	35.2
Phoma sp.	—	2.1	—	—

1) Totals of 20, 91, 127 and 164 suspectable samples were collected in Jan., July, Aug. and Oct. 1990 and pathogenic fungi were isolated from 6, 48, 43 and 88 samples of each sampling respectively.

其中 *P. citrophthora* 及 *P. parasitica* 爲國內外首次報告。

由 *Phytophthora* 所引起的果實疫病，病徵與*Phomopsis* sp.、*Colletotrichum* sp. 及 *Phoma* sp. 引起者不同，前者病勢發展快速，當果皮變色後，通常果肉組織也同遭病菌感染而變色，5～6天後整果變黑，後三者引起者病勢進展緩慢，通常果皮僅呈現局部黑色斑塊，患處容易龜裂，內部變色通常止於鱗目組織，但與*B. theobromae* 引起者卻極不容易區別，雖然 *Phytophthora* 引起者病部前緣通常呈淡褐色水浸狀，而後者則呈暗褐色，與健部間界線較明顯，但病徵常因環境及品種不同而略有改變，如僅就病徵診斷病害種類，並據以推薦防治法，可能會經常誤判，本研究以水瓊脂平板直接行組織分離，*Phytophthora* 在其上經3～4天後即長出稀疏的珊瑚狀菌絲，並隨即著生胞囊，與其它病菌相較頗不相同，筆者等依此特性以肉眼鑑別並輔以鏡檢，準確率幾達100%，在其它更快速的鑑別方法未確立前，不失爲可靠的診斷法。

由*P. citrophthora* 引起的果實疫病由於以往未曾詳細調查，而果農在疏果時又都將黑變果一併剪除，剪除掉的果實，不論病果或健果，棄置於地上後都會整粒變黑，因此，其實際發生比例如何，造成的損失多大，尙無法確定，但本研究在幾次全面調查中發現，還著生於枝條上的果實，出現類似病徵者並不普遍，葉片受感染的情形亦罕見，迄今僅知位於台東市郊的二處果園，於1989年12月至1990年1月間曾較普遍地發生。本菌生長最適溫24～28℃，當溫度超過33℃時即不生長，台東地區於7～9月間正值夏果盛期，而此段期間溫度偏高，10月至翌年1月則爲冬果盛期，此時溫度較低，雨水亦不多，該菌猖獗成災的機會不大，3～6月正值大修剪後，番荔枝大多未著果，因此推斷由*P. citrophthora* 引起的果實疫病在目前的栽培制度下，於台東地區應不致釀成巨災。*P. nicotianae* 屬於嗜高溫菌，於7～9月間，尤其是颱風過後，應有可能較普遍發生，本年度調查中雖於夏果上未曾發現該菌，但爾後值得進一步追蹤調查。至於其它以人工接種可以致病的 *Phytophthora* 或該屬其它種類，在田間是否存在，本省其它地區疫病菌危害番荔枝情形如何，也待進一步探討。

P. citrophthora 引起的病害，在本省經記錄者僅柑桔褐腐病及草莓果腐病[3,13,15]，不過其分佈卻相當廣泛，幾乎遍及全省，自柑桔根部及桔園土壤中常可分到該菌[6]，台東地區爲本省柑桔重要產區，感染番荔枝的菌源最初可能來自柑桔園，而果農在剪除病果後，通常將其棄置果園，病菌可能以厚膜胞子殘存，而成爲下一季發生的主要感染源。本研究中發現的*P. nicotianae* 即原稱的 *P. parasitica*[13]，其寄主極爲廣泛，在本省經記錄者約33種，自土壤中也常可分到該菌，其主要分佈於本省中部以南地區[3,13,15]，在台東地區普遍種植的荖花（*Piper betle* L.）、柑桔、百香果均爲其寄主，因此其對番荔枝夏果的威脅反倒更值得注意。

P. citrophthora 爲異絲型（heterothallic）疫病菌，本省以往發現的菌株都屬於 A^1 配對型[6,13,15]，本研究中供試的三個菌株經測試，結果亦同，是否該菌在本省眞無 A^2 型存在，值得擴大採樣證實。本菌的有性繁殖以往不爲人知，Savage 氏等[19]於1968年首先報告本菌形成的藏卵器、藏精器及卵胞子，本研究中供試的菌株經與 *P. parasitica* 的相對型菌株配對後也會產生有性繁殖器官，但數量極少，僅見的一組藏卵器及藏精器，除藏卵器體形較其報告者爲小外，其它特性均相似。

作物疫病防治除抗病育種外，首重田間管理，*Phytophthora* 引起的番荔枝果實黑變病，目前僅零星發生於部分果園，由於現行的栽培制度不利於該病發生，果農如能注意清除病果、加強果園通風，並採用草生栽培，則本病應不至於造成重大危害。施用殺菌劑也是防治疫病的可行方法，本研究中供試的多種殺菌劑中，以鋅錳滅達樂對 *P. citrophthora* 的防治效果最優，與其同類的銅滅達樂次之，該類藥劑近幾年來廣泛被應用於防治屬於卵菌綱（Oomycetes）的眞菌，效果頗爲突出，但有關病菌出現抗藥性的報告也隨之出現[1,3,10,18]，因此，在必要時，有節制地施用該類藥劑，不失爲理想的配合防治措施。普拔克及福賽得爲近幾年來新興的疫

病防治藥劑，其中普拔克及福賽得在生體外（*in vitro*）對疫病菌並無抑制能力，而須進入植物體內後，經代謝轉換才能表現殺菌效果，因此，該類藥劑通常須提早施用方能收效[5,18]，本研究中該兩藥劑防病效果不如理想，可能是藥劑處理與接種時間相隔太短所致。

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ABSTRACT

Huang, T. C., Leu L. H. and Lee, H. L. 1991. **Phytophthora fruit rot of *Annona squamosa* L. caused by *Phytophthora citrophthora* and *P. nicotianae*.** Plant Prot. Bull. 33:103-112. (Department of Crop Environment, Taitung Distrist Agricultural Improvement Station, Taitung, Taiwan, R.O.C.)

Phytophthora fruit rot of sugar apple (*Annona squamosa* L.) caused by *Phytophthora citrophthora* and *P. nicotianae* was first found in January and October 1990, respectively. The infected fruits develop purplish black or brownish black discolored areas on surface at first, followed by discoloration of interior tissues to light brown or dark brown, then become completely black and mummified in 5 to 6 days. The cardinal temperatures for mycelial growth of *P. citrophthora* were 10, 26 and 33℃. Its sporangia are non-deciduous papillate, ovoid to lemon shape, with average size of 45.5×30 μm, but often become distorted. It is heterothallic and all of isolates tested belong to A^1 type. The lowest concentration for its zoospores to infect non-wound fruits lay between 3.3-8.8 × 10^2spores/0.2 ml. The disease usually occurred sporadically during October to January of next year. *P. nicotianae* from diseased fruit is characterized by its broadly ovoid papillate sporangia, with average size of 37 × 30 μm. The lowest and highest temperatures for its mycelial growth were about 10℃ and over 37℃, respectively. Its frequency of being isolated from diseased fruits was less than that of *P. citrophthora*. 58% Ridomil-MZ WP at the rate of 2.5 g/l and 76.5% Ridomil-Cupnait WP at the rate of 1 g/l were found to be significantly effective on the prevention of fruits from the infection of *P. citrophthora*. However, all fungicides applied after infection failed to inhibit the development of the lesion.

(Key words: sugar apple, fruit disease, *Phytophthora citrophthora, Phytophthora nicotianae*)

土壤病原生態與防治研討會專刊 113~123, 1991

利用土壤添加物防治作物之土壤傳播性病害

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摘　要

黃振文 1991 利用土壤添加物防治作物之土壤傳播性病害　植保會刊 33:113～123

利用有機添加物可以補充地力，維繫作物的生產外，亦可抑制作物之土壤傳播性病害的發生。大豆綠肥、甘蔗葉渣、苜蓿粉、闊葉樹皮、雞糞、甘藍及芥菜葉渣和魚粉等是常用的有機添加物。至於無機添加物有矽酸爐渣、碳酸鈣、硫磺粉、硫酸鈣及化學肥料等。由於農田經常存在多種根部病害問題，且爲了有效利用有機與無機添加物彼此間的優點。因此，結合有機與無機添加物以發展「合成土壤添加物」是綜合防治作物根部病害的一種策略。目前，S-H 與 SF-21 混合物是兩種已發展成功的合成土壤添加物。S-H 混合物可以防治西瓜蔓割病，蘿蔔黃葉病，芥菜根瘤病、豌豆萎凋病，胡瓜猝倒病與疫病及番茄青枯病。而 SF-21 混合物則可防治由 *Rhizoctonia solani, Pythium aphanidermatum* 及 *Fusarium moniliforme* var. *subglutinans* 三者所引起的溼地松苗猝倒病。

（關鍵字：土傳病害，土壤添加物，S-H 混合物，SF-21 混合物）

緒　言

在自然的環境中，要維繫農作物的生產潛能，必須使農田免於酸化、毒傷及沖刷，並須經常補充作物生長所需的各種營養與有機質[27,32]。然而，台灣自光復以來，農友普遍採行集約栽培及偏用化學肥料，同時又忽略有機質的補充，因此約有60%左右的農田，其土質偏酸，作物的根部病害逐年遽增，導致蔬菜、果樹等作物的生產力急速下降。近年來，本省常見的作物根部病害有十字花科蔬菜根瘤病，葫蘆科、茄科疫病，香蕉、芹菜、蘿蔔黃葉病，西瓜及香瓜蔓割病，十字花科、豆科菌核病，茄科立枯病、青枯病、根瘤及根腐線蟲病，豆科根腐病、萎凋病等，都是值得重視的病害問題[13,61]。

土壤是有機與無機的綜合體，其傳播性病害的管理工作，常受制於土壤的環境，土媒病原的習性與棲群動態，以及作物生長繁殖的遺傳因子，導致成效不彰[13]。因此，學者們爲突破根部病害防治的瓶頸，除加强種苗檢疫，抗病選種或育種，輪作或休耕，土壤化學燻蒸，灌注化學殺菌劑或線蟲劑與找尋拮抗菌等防治策略外，就是利用土壤添加物以降低根部病害的發生及保護植物的健康[5,6,12]。

土壤添加物的應用

自古以來，我國農民多習慣在農田中施用人畜糞便、作物殘餘物、草木灰或泥土等土壤添加物，以增進土壤肥力，並維持作物之生長，但卻從未留意這種農事的操作具有減少或增進土傳性病害發生的功效。六十年前，Sanfard[57]有效利用綠肥添加物防治馬鈴薯瘡痂病 [*Streptomyces* (*Actinomyces*) *scabies* (Thaxt.) Waks

& Henrici]的報導，給予土壤傳播性病害的防治研究者一個啓示是：「適當的經營與管理土壤，可有效的控制土壤環境，並抑制作物根部病害的發生」。隨後，許多植物病理學者逐漸研究作物殘渣、樹皮、堆肥、汚泥、綠肥及大豆粉等添加物的利用，以防治土壤傳播性病害（表一）。Lewis和Papavizas[47]指出甘藍、芥藍和芥菜渣添加於土中可以顯著降低豌豆根腐病（*Aphanomyces euteiches* Drechs）的發生。Fassi *et al*[29]利用泥炭土混合堆肥的添加處理，有效的防治松苗舞病。Vaartaja和Bumbieris[63]在奧大利報導每英畝苗床添加15噸半腐熟的松皮與鋸屑，可具扼止松苗猝倒病的效果。Snyder *et al*[60]發現添加成熟大麥桿（mature barley straw）能有效抑制豆類根腐病〔*F. solani* Mart. f. sp. *phaseoli* (Burk) Snyder & Hansen〕的發生。Sequeira[58]利用蔗葉渣20～60噸/英畝防治香蕉黃葉病 *F. oxysporum* Schl. f. sp. *cubense* (E. F. Smith) Snyder & Hansen的效果優於豆類殘渣及糞便的處理。隨後，他又報導尿素可使香蕉黃葉病大爲下降[59]。Papavizas、Lewis及Adams[24,53]認爲添加有機物可以改變碳氮比，是達成防治 *F. solani* f. sp. *phaseoli* 的主因。Guy等[33]指出添加幾丁質於土中可以減少豌豆萎凋病的蔓延。但Guy及Baker[33]、Snyder *et al*[60]也曾使用纖維，綠大麥桿等處理，卻增加豆類萎凋病的嚴重度。筆者[7,11]發現添加洋菇堆肥可降低西瓜蔓割病菌〔*F. oxysporum* Schl. f. sp. *niveum* (E. F. Smith) Snyder & Hansen〕的存活，但添加鐵杉鋸屑卻可延長病原菌的存活時間。土中施用麥桿，使小麥根腐病菌（*F. solani* 及 *F. roseum*）的繁殖與存活增長，導致根腐病更趨嚴重[28,39,55]。紫花苜蓿（Alfalfa）添加於土壤之後，除了可以減輕白絹病菌（*Sclerotium rolfsii* Sacc.）之爲害外[20,43]，尙可減輕其他 *Phytophthora*、*Fusarium* 及 *Thielaviopsis* 等菌所引起的根部病害[31,40]。添加高量的紫花苜蓿，6～8星期以後，可以破壞土中所有的菌核；添加低量者，12星期後，有90%的菌核遭到破壞；而未添加者，僅有25%之菌核受害[43]。蔡、林兩氏[19]發現篦麻粕、海草、糖蜜及蝦殼等添加物，可以降低柑桔線蟲（*Tylenchulus Semipenetrans* Cabb.），根腐線蟲（*Pratylenchus coffeae*）及螺旋線蟲（*Rotylemchus* spp.）的蟲口數，但鋸木屑、泥炭土、黃豆粉等卻可增進柑桔線蟲與根腐線蟲的繁殖與存活。綜合上述學者的研究工作，利用添加物除可以防治作物根部病害外，亦有增進病害發生者。

合成土壤添加物的開發與利用

施用土壤添加物於不同種類的土壤，往往未能有效的控制作物病害，更何況，在農田中常有兩種或兩種以上的土壤傳播性病原菌共存

表一、利用土壤添加物防治土壤傳播性之作物病害的例子

Table 1. Examples of soil amendments for controlling soilborne crop diseases

作物病害名稱	病原學名	添加物	參考文獻
豌豆根腐病	*Aphanomyces euteiches*	十字花科蔬菜渣	47
香蕉黃葉病	*Fusarium oxysporum* f. sp. *cubense*	甘蔗葉渣	58
小麥根腐病	*Gaeumannomyces graminis* var. *tritici*	蛋白質類添加物、大豆粉、苜蓿粉、魚粉等	46
番茄根瘤線蟲病	*Meloidogyne incognita*	苜蓿、燕麥桿	42
萵苣菌核病	*Sclerotinia sclerotiorum*	廄糞	44
馬鈴薯瘡痂病	*Streptomyces scabies*	綠肥	50, 57, 64
菜豆根腐病	*Thielaviopsis basicola*	苜蓿、高麗菜莖葉、油種子粉	54
柑桔線蟲病	*Tylenchulus semipenetrans*	蝦殼、海草、糖蜜、蓖麻粕	19

一處，導致時有複合感染的病害問題。因此，許多的研究工作者經常發現單獨一種或兩種的添加物或作物殘渣無法有效的防治作物之根部病害。一般言之，每公頃的農田，至少須施用14～28公噸的有機添加物，才能達到防治根部病害的效果，然而在現階段的機械化經營體制下，這種用量是不合乎經濟原則，也無法爲農民所接受[52]。此外，在潮溼，寒冷的氣候條件下，鉅量施用有機添加物，偶有毒傷作物根部之虞[52]。相反的，利用無機添加物，除可直接促進作物的生長與抑制植物病原菌外[34]，它的農田施用量亦遠少於有機添加物的用量。然而，連續大量（重複）施用化學肥料（無機添加物），可導致土壤有機質的耗損及造成有毒物質的纍積[27]。爲了避免有機與無機添加物彼此間對於農田（農作物）的不良效果，且考慮採取兩者彼此間的優點，因此嘗試結合有機與無機添加物以開發合成土壤添加物（formulated soil amendment）[8,37,62]，確是今後綜合防治多種作物之土壤傳播性病害的努力方向。

民國69年，中興大學孫守恭教授及作者首先成功的發展一種合成土壤添加物，名曰S-H混合物[8]。這種混合物是由農業及工業副產物，再加三種肥料混合而成，其組成份包括：甘蔗渣4.40%、稻殼8.40%、蚵殼粉4.25%、尿素8.25%、硝酸鉀1.04%、過磷酸鈣13.16%及礦灰（矽酸爐渣）60.5%。將甘蔗渣，稻殼、蚵殼、礦渣磨成細粉，再加尿素，過磷酸鈣及硝酸鉀均勻混合，即是S-H混合物。礦渣爲中國鋼鐵公司之副產品，其成分爲：二氧化矽31%、氧化鈣44%、氧化鎂1.7%、氧化鋁18%與氧化鐵1%。S-H混合物在中興大學研究室與溫室證明效果穩定後，隨即於本省各地從事田間試驗，結果顯示其對十字花科蔬菜如蘿蔔、芥菜之黃葉病、青江白菜、芥菜根瘤病、西瓜蔓割病、扁蒲嫁接西瓜的苗期猝倒病，芹菜黃葉病、菜豆立枯病、甜椒白絹病、薑軟腐病等作物根部病害具有防治和增產的效果，同對也促進草莓、小白菜、甘藍菜及菊花的生長。例如(I)民國70年9～10月在台中縣新社水井，進行蘿蔔黃葉病防治試驗，S-H混合物處理區發病率爲8.2%，對照區爲41.8%；S-H區蘿蔔增產量爲對照區的1.89倍（圖一）。(II)民國70年10月～12月在屏東縣鹽埔鄉西瓜連作田，進行西瓜蔓割病防治試驗，在採收末期，S-H區發病率爲20.14%，對照區則爲74.6%。(III)民國71年2月～4月在桃園縣蘆竹鄉進行芥菜黃葉病防治試驗，S-H區發病率2.12%，對照區爲16.3%；S-H區芥菜產量爲對照區的2.29倍。(IV)民國71年1月～2月在雲林縣西螺鎮進行扁蒲嫁接西瓜之苗猝倒病防治試驗。處理S-H者，嫁接成活率高，植株生長較强壯，猝倒病的發生率大爲減少（圖二）。(V)民國70年9月～11月在屏東縣高樹鄉進行甜椒白絹病防治試驗，對照未處理區發病率爲11.67%，而S-H混合物處理區發病率僅0.56%。(VI)72年9月～12月在苗栗縣大湖鄉之草莓試驗田中，施用S-H混合物之處理區，其採收量爲對照未處理區的1.52倍，植株生長勢較强，開花期提前，果腐病發生率遽減。(VII)民國72年至73年興大植病系謝文瑞教授及其研究生們在桃園蘆竹鄉進行青江白菜根瘤病防治試驗，S-H混合物處理區的防治百分率比未處理對照區高出66%左右，並增加57.6%的收穫量。(VIII)民國73年至74年山地農牧局在嘉義縣番路鄉進行薑軟腐病防治試驗，施用S-H混合物的處理區使產量增加2～3倍，並減少軟腐病的發生。此外，S-H混合物亦被應用於防治豌豆萎凋病[2]，胡瓜猝倒病[48]與疫病[49]及番茄青枯病[3,4,23]等（表二）。

民國76年至79年間，筆者獲國科會與中興大學補助赴美進修時，也開發成功另一種合成土壤添加物，名曰SF-21混合物。SF-21混合物的組成是：松樹皮750克，硫酸銨35克，過磷酸鈣10克，氯化鈣30克，氯化鉀25克，硫酸鋁150克與甘油（10%）750毫升[35,37]。應用這個配方在溼地松的苗床，可同時防治*P. aphanidermatun* (Edson) Fitz, *R. solani* Kühn (AG-4)及*F. moniliforme* Sheld var. *subglutinans* (Wollenw & Reink)三者所引起的松苗猝倒病（圖三）[35,37]。此外，溴化甲烷燻蒸過後的苗床土之生態空隙，亦可由SF-21混合物加以保護，以扼止*Pythium* spp.再污染所構成的威脅。



圖一、在新社鄉水井村的蘿蔔連作田，利用 S-H 混合物防治蘿蔔黃葉病之成果。（其中左邊爲處理區；右邊爲不處理的對照區）

Fig 1. Radish plants growing in field infested with *F. oxysporum* f. sp. *raphani* and with soil (left) amended with S-H mixture at a rate of 1200 kg/ha and (right) not amended.



圖二、在西螺振興里的育苗土添加 S-H 混合物防治西瓜苗猝倒病的成果。（右邊爲處理區；左邊爲對照區）

Fig 2. Watermelon plants growing in soil infested with *Fusarium oxysporum* f. sp. *niveum* and *Pythium debaryanum* and with soil (right) amended with S-H mixture at a rate of 1200 kg/ha and (left) not amended.

表二、本省利用合成土壤添加物（S-H混合物）防治土壤傳播性之作物病害

Table 2. Control of soilborne crop diseases with a formulated soil amendment (S-H mixture) in Taiwan

作物病害名稱	病原學名	防治效果	參考文獻
西瓜蔓割病	*Fusarium oxysporum* f. sp. *niveum*	減少病害，抑制厚膜胞子發芽，且促進發芽管瓦解	8, 9, 62
蘿蔔黃葉病	*F. oxysporum* f. sp. *raphani*	減少病害，增加蘿蔔產量	14, 62
青江白菜根瘤病	*Plasmodiophora brassicae*	減少病害，降低根毛受害，增加青江菜產量	15, 16, 17 18, 21
豌豆萎凋病	*F. oxysporum* f. sp. *pisi*	抑制發病率	2
胡瓜猝倒病	*Pythium aphanidermatum*	減少卵胞子存活與發病率	48
胡瓜疫病	*Phytophthora melonis*	減少發病率，但需配合噴佈銅滅達樂	49
甜椒白絹病	*Sclerotium rolfsii*	抑制菌核發芽與發病率	62
番茄青枯病	*Pseudomonas solanacearum*	在溫室內，可減少病菌存活力與病害的發生	3, 4, 23

添加物防病抑菌的原理

有機添加物可以增强土壤微生物的活力與競爭作用，並誘使植物病原菌的接種源受害及利於作物的生長[26,28]。Adams *et al*[25]認爲土中添加纖維類的物質，可提高土壤的靜菌作用，以扼止豆類根腐病的發生。Rao[56]推論添加有機營養物，可以改變 *F. oxysporum* f. *vasinfectum* 的致病性。然而，Huber *et al*[38]卻認爲有機物的添加可以强化病原菌的腐生生長優於寄生行爲（Parasitic activity）。Sequeira[58]詳述添加有機物以減少 *F. oxysporum* f. *cubense* 病菌量的原因有三，即 (I) 促進厚膜胞子的發芽，(II) 誘發土壤細菌以分解菌絲及薄壁胞子，(III) 抑制厚膜胞子的再形成。

Lewis 和 Papavizas[47]添加十字花科蔬菜菜渣可抑制豌豆根腐病（*Aphanomyces euteiches*）的原因，在於這類菜渣經分解後，可以釋放硫醇（mercaptan），硫化物（Sulphides），異硫氰化物（Isothiocyanates）等氣體。這類氣體與土壤燻蒸劑衛本（Vapam）和邁隆（Dazomet）在土中所放出的異硫氰酸甲酯（Methyl isothiocynate）具有相以的殺菌效果。Gibert *et al*[30]報導在土中添加紫花苜蓿所釋放的揮發性物質，可以迅速提高土壤微生物的活力。此類揮發物質是由 20 種以上的揮發性化合物組成，其中乙醛（Acetaldehyde）、異丁醇（Isobutyraldehyde）、異戊醛（Isovaleraldehyde）、甲基丁醇（Methylbutanol）及（或）戊醛（Valer aldehyde）、甲醇（Methanol）及乙醇（Ethanol）爲主要的有效物質。乙醛可以單獨增加土壤眞菌之數目，而甲醇則有利於促進細菌的增殖。若混合乙醛與甲醇則有助於增加細菌及放射菌的數目[51]。

合成土壤添加物含有兩種以上的有機物及無機物，因此其防病與抑菌的原理常隨添加物與病原菌種類的不同而有所差異。孫、黃兩氏[9]指出 S-H 混合物抑制蘿蔔黃葉病菌厚膜胞子的發生與分解發芽管之重要成分是礦灰及蚵殼粉；至於分解西瓜蔓割病菌發芽管的主要成分則是礦灰。礦灰的五種成分中，以鈣鹽及鐵鹽爲抑制厚膜胞子發芽與瓦解發芽管的重要鹽類。施用 S-H 混合物於土壤後，可增進有益眞菌及放線菌的密度，並可利用其蔗渣與谷殼粉等有機物之成分以延續有益微生物的存活。S-H 混合物也可以減少西瓜根圈的蔓割病菌，並提高西瓜根的數目與重量。歸言之，S-H 混合物的防病機制是下列數因子綜合表現的結果：即 (I)

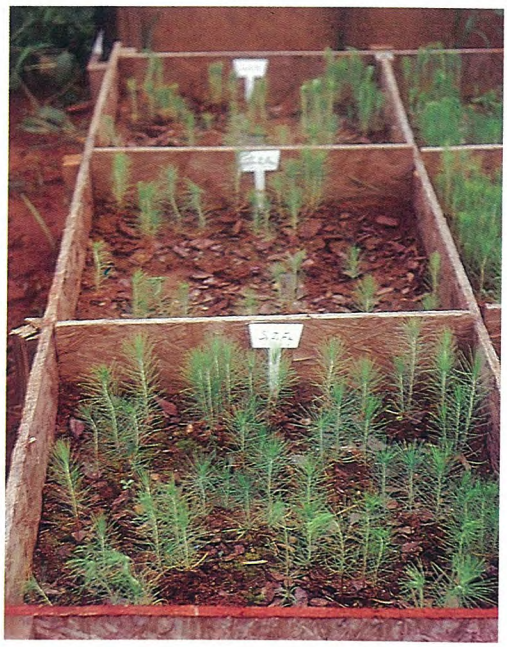
其無機鹽類可直接抑制病原菌，並可中和土壤酸鹼度，提高土壤 pH 值；(II) 增加土壤中有益微生物的數量，進而抑制或瓦解病原菌；(III) 含豐富的營養及多種微量元素，可補充作物生長的需要，增加作物根系的發育，並增強作物的抗病力。至於 S-H 混合物防治其他土壤傳播性病害的有效因子有：(I) S-H 混合物中的尿素可釋放出氨氣，因此可以有效的抑制甜椒白絹病菌的發芽[62]及防治胡瓜猝倒病的發生[48]；(II) S-H 混合物含有鈣鹽及提高土壤 PH 值，所以可以防治十字花科蔬菜根瘤病[16,17]；(III) S-H 混合物的礦灰及尿素是番茄青枯病的主要抑制成分[49]。筆者在美國喬治亞大學進修時，所發展的 SF-21 混合物，可以同時防治 *Rhizoctonia solani* (AG-4) 和 *Pythium aphanidermatum* 所引起松苗猝倒病，其防病與抑菌原理是：(I) SF-21 混合物可以促進 *Trichoderma harzianum* Rifai 及 *Penicillium oxalicum* currie et Thom 大量的繁殖與存活（圖四），因而抑制 *R. solani* 對松苗的致病能力；(II) SF-21 混合物的有機物與無機物成分可降低土壤酸鹼值與直接抑制 *P. aphanidermatum* 之菌絲及游走子發芽管的生長；又 SF-21 混合物誘使土壤微生物大量的繁殖，可加速瓦解游走子的發芽管；(III) SF-21 混合物也可以強壯松苗根系的發育與生長[36,37]。

結　論

土壤添加物影響作物之土傳性病害的發生，大致可分爲三類，即 (I) 有的可以減少病害，(II) 有的則使病害增加，(III) 有的與病害的發生無顯明關係。理論上，作物殘餘物與土壤有機添加物可減少病害發生的原因是添加物可 (I) 改變病菌之腐生生活；(II) 產生刺激物或抑制物質，以降低接種源密度；(III) 提供營養物質，平衡土壤之碳氮比；(IV) 改變土壤微生物相，增強土壤之靜菌作用；(V) 改變土壤理化性質，以增強作物的生長。此外，添加物亦可影響到作物葉部病害的發生。顏氏等[22]指出水稻田施用谷殼後，可增加土壤與稻葉片之矽、鉀含量，因而增強水稻抵抗葉與穗之稻熱病。又土中施用矽酸爐渣亦可減少水稻胡麻葉枯病的發生[1]。

土壤添加物防病的功效，常受制於農田的生態環境因子，土壤質地與肥力[10]，作物的特性，病原菌的對象，接種源密度與作物栽培的序列[55]等，因此，要成功的利用添加物以防治作物病害，必須深入研究土壤添加物的特性與防病機制，同時也得清楚的掌握土壤的各種環境因子。Irving[41]給「綜合防治（Integrated control）」下了一個定義，就是巧妙而協和的應用各種防治策略以使環境的污染及人類的損失傷害減至最低，並使自然防治法得以有效的發揮。過去，有許多殺菌劑除可直接抑制植物病原菌外，同時又可誘使土讓的微生物對病原菌的拮抗作用增強，因而達到防治病害的效果，這種現象也被稱爲「綜合防治」[26]。按 S-H 及 SF-21 兩混合物的防病機制觀之，它們利用生物因子與非生物因子以防治多種土傳性病害，也是一種「綜合防治」的表現。事實上，合成土壤添加物的發展是以考慮農業生態體系內生物間的平衡爲著眼點，除注意作物生長的營養外，亦考慮有益微生物的繁殖與存活。因此，成功的合成土壤添加物，其成分往往可以弱化植物病原菌的生命活力，並使拮抗微生物得以有效的攻擊病原菌。

世界各地均考慮以生物防治來減少農藥的污染問題，但成功的生物防治的實例並不多。Kuhlman[45]認爲要達成生物防治的目標，拮抗微生物須具備下列六個要件，即 (I) 要能迅速的散佈；(II) 任何環境下，均可感染病原菌；(III) 在病原菌爲害作物之前，即已成功的完成攻擊病原菌的任務；(IV) 能弱下或殺傷病原菌；(V) 能持續的增殖；(VI) 對於寄主植物不具有病原性。其中，如何使拮抗菌在土中與根圈繁殖（增殖）是使生物防治臻至成功的最重要手段。合成土壤添加物，如 S-H 和 SF-21 混合物，可以引誘土中拮抗菌增殖，又可充作拮抗菌存活的基質。因此，筆者建議今後生物防治的努力方向是：「發展有利於拮抗菌繁殖的合成添加物，以使拮抗菌得以配合，並發揮抑菌與防病的效果。」



圖三、在美國喬治亞州雅典城利用 SF-21 混合物防治溼地松苗猝倒病之成果。（前區爲處理者；中間區爲對照）。

Fig 3. Damping-off of slash pine seedlings, caused by *Rhizoctonia solani* (AG-4), controlled by amending soil (frontal microplot) with SF-21 mixture at a rate of 2000 kg/ha; soil in central microplot not amended.



圖四、土壤添加 SF-21 混合物 (SF) 可促進 *Trichoderma harzianum* (T) 及 *Penicillium oxalicum* (P) 在土壤表面大量繁殖的情形。

Fig 4. Proliferation of *Trichoderma harzianum* (T) and *Penicillium oxalicum* (P) stimulated by SF-21 mixture (SF) on soil surface.

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ABSTRACT

Huang, J. W. 1991. **Control of soilborne crop diseases by soil amendments.** Plant Prot. Bull. 33:113-123. (Department of Plant Pathology, National Chung Hsing University, Taichung, Taiwan, R.O.C.)

When the soil elements essential for efficient plant nutrition and economic production are low in availability or are not in balance, soil amendments and chemical fertilizers are required. The use of soil amendments to intensify microbiological activity and enhance competition among soil microorganisms results in lysis of inoculum structure of pathogenic fungi. Therefore, soil amendments are also frequently recommended to prevent the increase of soilborne plant pathogens in cultivated soil. Since 1979, formulation of soil amendments has been devised to control root-infecting fungi with minimal amounts of amendments or to alleviate root disease problem with amendments used as an integrated part of an economical, feasible disease control program. Two formulated soil amendments, S-H and SF-21 mixtures, have been successfully developed for controlling soilborne crop diseases. S-H mixture, consisted of 4.4% bagasse, 8.4% rice husks, 4.25% oyster shell powder, 8.25% urea, 1.04% potassium nitrate, 13.16% calcium superphosphate, and 60.5% mineral ash (slag), has been used to effectively control fusarial wilt of watermelon, radish, and pea, club root of crucifers, pythium damping-off and phytophthora blight of cucumber, and bacterial wilt of tomato in Taiwan. Furthermore, SF-21 mixture, consisted of 750 g milled pine bark, 35 g $(NH_4)_2SO_4$, 10 g triple superphosphate, 30 g $CaCl_2$, 25 g KCl, 150 g $Al_2(SO_4)_3$ and 750 ml glycerine (10%, v/v), was able to significantly reduce damping-off of slash pine caused by *Rhizoctonia solani, Pythium aphanidermatum* and *Fusarium moniliforme* var. *subglutinans,* and promoted growth of pine seedlings in the United States.

(Key words: soilborne crop diseases, formulated soil amendment, S-H mixture, SF-21 mixture)

土壤病原生態與防治研討會專刊 124~132, 1991

Somaclonal Resistance in Cavendish Banana to Fusarium Wilt

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ABSTRACT

Hwang, S. C. 1991. **Somaclonal resistance in Cavendish banana to fusarium wilt.** Plant Prot. Bull. 33:124-132.

Somaclonal variants of Giant Cavendish derived from meristem culture were used for screening for resistance to fusarium wilt caused by *Fusarium oxysporum* f. sp. *cubense* Race 4. As a result of this screening program, 9 somaclones showing resistant reaction had been obtained. Four of them (GCTCV-44, -104, -105, -119) were highly resistant to the disease, while the others (GCTCV-46, -53, -62, -201, -215) were moderately resistant. Somaclones with high level of resistance had a percentage of disease incidence of less than 10% and those with moderate level of resistance had 11-30%, compared with over 70% in Giant Cavendish. All resistant clones differed from the parent, Giant Cavendish, by possessing combinations of inferior agronomic characters. Improved variants were obtained from a large planting in the field of plantlets of these resistant clones. The majority of improved variants retained wilt resistance. GCTCV-215-1 appears to be the most promising resistant variety because of having both acceptable horticultural characteristics and marketable fruit qualities. Disease incidence of GCTCV-215-1 was 17.2% when 2-month-old plantlets were used as planting material and it was 5.2% for suckers, compared with about 75% in Giant Cavendish. Plantlets of GCTCV-215-1 had been planted in 700 ha of infested banana fields during the period of March-May 1990 for further evaluation of the stability of disease resistance under a wide range of environmental conditions.

(Key words: banana, Fusarium wilt, disease resistance)

INTRODUCTION

The Cavendish cvs. Giant Cavendish and Robusta have been seriously affected by Race 4 of *Fusarium oxysporum* Schlect. f. sp. *cubense* (E. F. Smith) Snyder and Hansen in Taiwan in recent years[1]. Damage by the pathogen first appeared in 1967 and since 1977 has become widespread in the major banana-production areas in the country, de-

stroying over 500 ha annually[13]. Outbreaks of fusarium wilt on Cavendish cultivars have also been reported from Australia, South Africa, the Canary Islands and the Philippines[7,8,11]. Prior to 1960, fusarium wilt of banana, caused by Race 1 of the pathogen, destroyed more than 40,000 ha of bananas in Central and South America over a period of 50 years[9]. The disease has been under control there since the susceptible cv. Gros Michel was replaced with resistant Cavendish cultivars. Race 2, capable of attacking cv. Bluggoe and Race 3, which attacks *Heliconia* species, are of minor importance[9].

Previous control measures in Taiwan which consisted of field sanitation, soil fumigation and liming, were not successful[1]. Although crop rotation with paddy rice has been shown to be an effective method for controlling the disease[1], replanting of banana in the reclaimed infested fields allowed only one to two years of profitable banana production before the disease increased to epidemic levels. Therefore, it is necessary to develop resistant cultivars to replace the present susceptible Cavendish cultivars.

All commercial banana cultivars tested previously in Taiwan were susceptible to Race 4 of *F. oxysporum* f. sp. *cubense*[4]. Searches for a resistant mutant were made among survivors in fields of Cavendish cultivars devastated by wilt, but without success[13]. Since about 3% of the plantlets derived from tissue culture of Giant Cavendish are mutants [2], these plantlets were screened for resistance to Race 4 beginning in 1984.

MASS PROPAGATION OF PLANTLETS AND SCREENING PROCEDURES

The method of Ma and Shii[6] was used to induce the formation of adventitious buds from explants obtained from shoot tips of suckers of Giant Cavendish. Subculture of the buds was made once a month and continued 6-7 times until a sufficient population of buds was achieved. Procedures described by Hwang *et al*[3] were used to induce roots and promote shoot development from the adventitious buds. Plantlets were maintained in a green-house for 2 months before planting in a field in which about 60% of the Cavendish plants had shown wilt symptoms. After diseased tissue had been plowed into the soil, a pathogen population of about 300 to 1,000 propagules per g of soil was maintained throughout the period of testing. A large number of 2-month-old plantlets were planted in the nursery, giving a planting density of about 20,000 plants per ha. After 3-4 months, the surviving plants were dug up and the rhizomes were cut and examined for symptoms of fusarium wilt. Those free of symptoms were multiplied by shoot-tip culture for further tests. When suckers of the surviving plants were used for planting, rhizomes were examined for symptoms by shaving with a knife[13]; only disease-free suckers were tested.

Tissue-culture-derived plantlets have been propagated commercially since 1982 for the banana planting program in Taiwan[3]. A few banana plantations which were established with these plantlets became infested with the wilt pathogen after 2-3 years. Suckers of survivors in seriously diseased plantations were also selected and multiplied *in vitro* for resistance testing.

RESISTANT MUTANTS OBTAINED FROM PLANTLETS

Of about 20,000 plantlets screened thus far, six have been found to be highly resistant to the pathogen (Table 1). After one year,

all mature plants grown from suckers of the six remained healthy, while 60% of the susceptible control plants were diseased. Resistance of the six variants remained high during a second and third generation, regardless of whether plantlets or suckers were used to propagate the plants. Results of a greenhouse experiment indicated that all six clones were resistant to Race 1, as well as Race 4 of *F. oxysporum* f. sp. *cubense* and hence there is no evidence that there is a breakdown of resistance to Race 1 during *in vitro* manipulation.

The resistance of these clones is affected by the inoculum density of the pathogen in soil. Results of an artificial inoculation test showed that at inoculum densities of 300 propagules per g of soil, all plantlets of the resistant clones GCTCV-53 and GCTCV-119 remained healthy under greenhouse conditions, while 65% of the plantlets of the susceptible parent were killed. To cause an incidence of 50% disease in the parent, GCTCV-53 and GCTCV-119, inoculum densities of 100, 850 and 1,000 propagules soil $^{-1}$ were required, respectively. GCTCV-119 appears to be more resistant than GCTCV-53.

All six resistant clones differed from the parent, Giant Cavendish, by possessing combinations of inferior agronomic characters such as excessive height, weak petiole, small fruit bunches and lengthened growth period (Table 2).

IMPROVEMENT OF RESISTANT MUTANTS

All six resistant clones had no commercial value because the fruit was under the minimum standard of quality. Selections for mutants with commercially acceptable fruit were made from tissue-culture progenies of the resistant clones (plantlets of resistant

Table 1. Incidence of fusarium wilt in six tissue culture-derived variants of Giant Cavendish[1)]

Clone	Planting material	Number evaluated	% Diseased
GCTCV-40	Sucker	329	0.5
	Plantlet	965	0.3
GCTCV-44	Sucker	118	2.0
	Plantlet	250	0
GCTCV-46	Sucker	268	1.8
	Plantlet	593	0.5
GCTCV-53	Sucker	184	0.2
	Plantlet	467	3.9
GCTCV-62	Sucker	40	3.0
	Plantlet	45	11.1
GCTCV-119	Sucker	75	0
	Plantlet	650	2.2
Giant	Sucker	207	39.5
Cavendish	Plantlet	863	59.7

1) Average disease incidence for 3 generations of each clone. The variants and Giant Cavendish were screened in a field naturally infested with Race 4 of *fusarium oxysporum* f. sp. *cubense*.

Table 2. Major agronomic characteristics of resistant clones derived from tissue culture of Giant Cavendish relative to the normal parent

Clone	Salient features
GCTCV-40	Taller, thinner pseudostem with wide spacing of internodes; weak petioles; narrow, drooping leaves (resembles tetraploid)
GCTCV-44	Shorter, thinner pseudostem, weak petioles and drooping leaves; normal bunch but with weak finger neck (resembles tetraploid)
GCTCV-46	Black spots on pseudostem, petiole and leaf sheaths; more upright leaves; smaller bunches with short fingers
GCTCV-53	Dark green pseudostem and leaves; drooping leaves; male bud narrow and elongate; smaller bunches with short fingers
GCTCV-62	Pale green pseudostem and leaves; slow to produce suckers; smaller bunches and fingers
GCTCV-119	Taller, thinner pseudostem; wavy lamina with pronounced purple spotting; rose shades in pseudostem, petioles and leaf sheaths when young; loosely-packed pseudostem at maturity

clones were propagated by the same method as described above). When large numbers of plantlets of the resistant clones were planted in the infested field, a few plants with better fruit quality were found in each clone (Table 3). These plants had thicker pseudostems, grew faster and produced a bigger bunch than their respective resistant parents. The percentages of improved variants found in plantlets of these six clones ranged from 0.2% to 10.1%.

Of four variants tested, GCTCV-44-1, GCTCV-53-1 and GCTCV-119-1 were highly resistant to Race 4, while GCTCV-40-1 had lost wilt resistance (Table 4). In a large scale field trial involving a total of 10 ha of plantings at various locations, the incidence of disease in GCTCV-44-1, GCTCV-53-1 and GCTCV-119-1 averaged 1.1, 6.3 and 3.9%, respectively, compared to 60.9% in Giant Cavendish.

The resistant variants yielded much heavier bunches than those produced by the original resistant clones (Table 5). For in-

Table 3. Frequency of variants with improved fruit quality among plantlets from tissue-culture-derived resistant clones

Clone	Number of plants evaluated	Improved variants	
		Number	Frequency (%)
GCTCV-40	1,040	105	10.1
GCTCV-44	1,219	3	0.2
GCTCV-46	592	8	1.3
GCTCV-53	220	12	5.5
GCTCV-62	45	2	4.4
GCTCV-119	45	4	8.9

Table 4. Disease incidence in improved, wilt-resistant variants of Giant Cavendish

Clone	Planting material	Number evaluated	Disease incidence[1)]
GCTCV-40-1	Sucker	47	57.1
	Plantlet	45	44.4
GCTCV-44-1	Sucker	81	3.2
	Plantlet	219	4.5
GCTCV-53-1	Sucker	300	4.7
	Plantlet	118	6.2
GCTCV-119-1	Sucker	376	3.1
	Plantlet	900	4.8
Giant	Sucker	157	50.9
Cavendish	Plantlet	150	63.3

1) Means of two trials in separate fields.

Table 5. Bunch weights for resistant clones, variants of the clones and Giant Cavendish

Clone	Bunch weight (kg)[1)]	
	Original	Variant
GCTCV-44	18.6 b	25.0 c
GCTCV-53	13.8 b	21.5 c
GCTCV-119	17.2 b	26.5 c
Giant Cavendish	25.9	

1) Bunch weights are means for 50 plants of each clone and its variant harvested in June and July. Means in rows followed by the same letter are not significantly different ($P>0.05$) according to Duncan's multiple range test. Mean bunch weight for Giant Cavendish is significantly greater than that for the variant of GCTCV-53, but not for the variants of GCTCV-44 and GCTCV-119.

stance, the weight per bunch on GCTCV-119 plants was 17.2 kg, while that of its variant reached 26.5 kg, an increase of about 54%. The bunch weights of GCTCV-44-1 and GCTCV-119-1 were about the same as those of normal plants, while GCTCV-53-1 produce a bunch about 17% lighter than normal. All the fruit produced by these three resistant variants ripened normally upon ethylene treatment.

In appearance, mature plants of the three improved resistant variants are distinct from the parental clones. GCTCV-119-1 takes longer to produce fruit and is taller than Giant Cavendish, whereas GCTCV-44-1 has weak petioles and drooping leaves, characteristics normally associated with tetraploids. These agronomic characters are considered to be deficiencies in banana plants. Although mature plants of GCTCV-53-1 were 30 cm shorter than those of Giant Cavendish, a desired character, they produced hands with shorter fingers. A search for resistant banana plants that lack agronomic defects is neeeded.

A PROMISING RESISTANT VARIANT FOR CONTROLLING FUSARIAL WILT

Recently, a new improved variant, GCTCV-215-1, with agronomic characters superior to the three clones mentioned above was obtained from the tissue culture plantlets of Giant Cavendish. The variant had a desirable level of resistance to fusarial wilt. Disease incidence of GCTCV-215-1 was 17.2% when 2-month-old plantlets were used as planting material and 5.2% when suckers were used for planting, compared with about 75% in Giant Cavendish (Table 6). Compared with Giant Cavendish, the variant was slightly taller, had a thinner pseudostem and took about one month longer from planting to harvest (Table 7). When mature, the leaves of this variant usually became necrotic on the margin, forming a brown or grey band of 1-2 cm wide along both sides of leaf margin. This distinctive feature of GCTCV-215-1 easily distinguishes it from Giant Cavendish. The variant yielded 28 kg per bunch which is about the same as that for Giant Cavendish. Fruit produced by the variant ripened normally upon ethylene treatment and had a shelf-life and flavor similar to that of Giant Cavendish. Because of having both acceptable agronomic characters and marketable fruit quality, GCTCV-215-1 appears to be a promising resistant variant for commercial planting for controlling fusarial wilt.

Table 6. Disease incidence in GCTCV-215-1 and Giant Cavendish

Clone	Planting material	Number evaluated	Disease incidence[1] (%)
GCTCV-215-1	Sucker	427	5.2
	Plantlet	1,881	17.2
Giant Cavendish	Sucker	560	77.8
	Plantlet	1,647	74.6

1) Means of 10 and 5 trials in separate fields for plantlet and sucker, respectively.

Table 7. Major agronomic characters of improved resistant clones of Giant Cavendish

Clone	Plant ht. (cm)	Circumference of pseudostem (cm)[1]	Growth cycle (mo)	Bunch weight (kg)[2]
GCTCV-44-1	260	66	12-13	25.0
GCTCV-53-1	257	75	11-12	21.5
GCTCV-119-1	333	83	14-15	26.5
GCTCV-215-1	286	74	13-14	28.0
Giant Cavendish	277	81	12-13	27.7

1) Measured at 30 cm above ground.

2) Average of 50 plants for each clone harvested in May and June.

DISCUSSION

Race 4, the cause of fusarium wilt of Cavendish bananas, is more destructive and has a wider host range than Race 1[4]. Finding a resistant clone to replace the susceptible Cavendish cultivars is urgently needed. Traditional banana breeding for improvement, including resistantce to fusarium wilt, has been based on obtaining useful tetraploids from crosses between triploids and diploids. However, due to low fertility inherent in most triploids and a lack of outstanding, fertile parents, banana breeding during the last 60 years has met with very limited success. Stover and Buddenhagen[10] have discussed, in detail, the reasons for the failure of previous breeding efforts to obtain useful resistant varieties.

Since bananas have been extensively cultivated on a large scale for a long time, it is commonly assumed that a substantial number of somatic mutants exist in nature. In a selection program to determine if a resistant mutant could have arisen from the local susceptible Cavendish cultivars in Taiwan, a large number of suckers from healthy plants which were growing in wilt-devastated fields were tested against Race 4 of *F. oxysporum* f. sp. *cubense*. No resistance to the pathogen was found[13]. Similarly, searches for a resistant mutant of the wilt-susceptible Gros Michel made in many countries in tropical America during the 1920s were not successful [9]. These results suggest that genetic variation occurring during the vegetative reproduction of cultivated bananas is rare under plantation conditions, and that the chance of obtaining a wilt resistant mutant in this manner is extremely small. In Taiwan, no significant variation was found in 40,000 mature plants grown from suckers in commercial plantations [2].

In contrast, great variability and high level of resistance to fusarium wilt were found in some clones of banana derived from *in vitro*-generated populations and subsequently propagated via shoot-tip culture[2,5]. Although all 6 resistant mutants originally obtained from the screening program were morphological variants producing fruit with poor quality[5], a few plants with improved fruit quality were found in their subsequent *in vitro*-derived progenies. The improved variants of GCTCV-44, GCTCV-53 and GCTCV-119 remained highly resistant to fusarium wilt. When these improved variants were planted in infested fields at various locations in Taiwan, their resistance to fusarium wilt was found to be stable over a wide range of environmental conditions.

The genetics of resistance of fusarium wilt of banana is not known. Race 4 can attack cvs, Gros Michel, Bluggoe, Pisang lilin and Latundan in addition to Cavendish cultivars[12]. The mutants derived from tissue culture of Giant Cavendish are resistant to both Race 1 and Race 4, but their reactions to other races remain to be tested. A susceptible segregant was found amongst the variants of the resistant clone GCTCV-40, which has narrow, drooping leaves. The susceptible revertant has erect leaves characteristic of normal plants. In contrast, the variants of GCTCV-44, GCTCV-53, GCTCV-119 and GCTCV-215 which retained the atypical foliage appearance, remained wilt resistant. This suggests that the gene(s) conferring resistance to Race 4 in these mutants may be linked to that (those) governing certain foliage characters. By continuous planting of a large number of tissue-culture-derived plantlets of resistant mutants (themselves of *in vitro* origin) in infested fields, it may be

possible to determine the genetic relationship between susceptibility and morphological characteristics.

The commercial value of the resistant variants depends on the productivity and fruit quality of these clones relative to the Cavendish cultivars which are now used by the international banana export trades. Among the resistant variants obtained thus far, GCTCV-215-1 is the best. It resembles Giant Cavendish except that it is slightly taller and has a longer growth cycle (Table 7). Plantlets of this variant were planted in about 700 hectares of infested banana fields during the period of March-May 1990 for further evalution on the stability of disease resistance under a wide range of environmental conditions. Further selection to obtain a superior resistant variant from plantlets of GCTCV-215-1 in widespread planting is in progress.

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摘　要

黃新川 1991 華蕉體細胞變異之抗黃葉病選種　植保會刊 33:124～132（屏東縣台灣香蕉研究所）

從北蕉（Giant Cavendish）之組織培養變異品系（Somaclonal variant）篩選已獲得9個品系對香蕉黃葉病病原菌（*Fusarium oxysporum* f. sp. *cubense* race 4）具有抗病性，其中4個品系（GCTCV-44, -104, -105, -119）呈高度抗病性，於重病蕉園測定其平均發病率低於10%；5個品系（GCTCV-46, -53, -62, -201, -215）呈中度抗病性，其平均發病率介於11～30%之間；對照一般北蕉之發病率爲70%以上。所有抗病品系均帶有不良的園藝變異性狀，從其大量種植之後代植株中可尋獲改良型品系。大多數改良型品系仍維持與原母系相同的抗病程度。田間試種結果顯示改良型品系之中以GCTCV-215-1之園藝性狀及香蕉產量品質較爲理想，具有推廣種植潛力。在重病蕉園種植GCTCV-215-1組織培養苗之發病率爲17.2%，吸芽苗之發病率爲5.2%，對照一般北蕉之發病率爲75%。79年3～5月期間於本省中南部香蕉黃葉病區種植GCTCV-215-1之組織培養苗700公頃，俾進一步探討其種植在不同環境條件下之抗病穩定程度。

（關鍵字：香蕉、香蕉黃葉病、抗病）

土壤病原生態與防治研討會專刊 133~141, 1991

台灣香蕉黃葉病之抑病土

莊再揚

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摘　要

莊再揚 1991 台灣香蕉黃葉病之抑病土　植保會刊 33:133～141

以土壤平板法測定厚膜胞子發芽率與小焦苗接種試驗之發病率呈顯著相關。本省中南部蕉區抑病土的比例很低，但半抑病土普遍存在。抑病土能抑制厚膜胞子發芽與新厚膜胞子的形成，並且加速病原菌菌絲的溶解，從而減少病原菌的存活。土壤抑菌性與土壤 pH 值及鈣含量呈顯著相關，但與土壤質地、有機質含量或鉀、鎂、磷等含量無關。分析微生物族群密度，祇有放射菌與厚膜胞子發芽呈負相關，而細菌和眞菌與厚膜胞子發芽無多大關係。抑病土經蒸氣消毒或添加抗生物質，會失去或降低抑菌性；添加營養液，初期降低抑菌性，但經 7 天後，抑菌性反而增強。在導病土中添加鈣化物，可增強抑菌性；但調整其 pH 由 5.0 至 7.5，對厚膜胞子發芽無多大影響。導病土加入 $CaCO_3$ 或 $CaCO_3$ 與 glucose-asparagine 混合液後，再加入微生物或 1% 抑病土，能誘發其抑病性，而且在導病土經蒸氣消毒後再加以處理，效果較佳。溫室內接種試驗顯示，以拮抗菌處理蕉苗並在病土添加碳酸鈣能降低發病，田間試驗亦有相同的結果。

（關鍵字：香蕉黃葉病、黃葉病菌、抑病土）

緒　言

感染本省華蕉（ Cavendish ）的黃葉病菌（*Fusarium oxysporum* Schl. f. sp. *cubense* (E. F. Smith)）於 1967 年首度在屏東縣林邊鄉發現後，經接種證明爲一新生理小種，定名爲 Race 4[7,15]，此生理小種在高屏蕉區逐漸擴散蔓延，並於 1981 年出現於中部地區彰化縣二水鄉的蕉園[1]。目前香蕉黃葉病已成爲威脅台灣香蕉產葉最嚴重的病害[14]，它能感染目前所有商品化的香蕉品種[6]。

本病爲重要的土壤傳播性病害，除了抗病品種外，並無其他有效的防治方法[13]。Hwang & Ko 曾利用香蕉組織培養苗篩選出抗病品系，但這些品系的農藝性狀不盡理想[9]，雖然其農藝性狀可加以改進而不喪失抗病性[10]，然而這些品系目前仍在觀察中，尚未完全商品化，因此尋找其他替代的防治方法亦應加以重視。

近年來，土壤傳播性病害抑病土之研究普遍受到重視[8,12]，中南美洲曾有香蕉黃葉病抑病土存在的報告[13]，他們依蕉園發生黃葉病至廢耕時間之長短，將蕉園土壤區分爲抗病土壤 (resistant soil)、半抗病土壤（ semi-resistant soil ）和非抗病土壤（ non-resistant soil ）。筆者多年來在高屏蕉區從事實際工作，發現香蕉黃葉病的發生，亦有類似中南美洲蕉園的現象；大部份蕉園發病後，擴散很快，幾年內就廢耕，但有部份蕉園雖然感染黃葉病，病勢進展卻很慢，更甚者，有些地區的蕉園發病很普遍，而其中部份蕉園根本不發病，顯示本省蕉

園亦可能有黃葉病的抑病土存在，故從事此方面的研究，本文乃是將這幾年的結果作綜合報導。

抑病土之篩選

自南投、彰化、雲林、嘉義、台南、高雄和屏東等地的發病與未發病蕉園採集69個土壤樣品，利用土壤平板法[11]測定厚膜胞子發芽。其中3個土壤樣品的厚膜胞子發芽率在10%以下，1個在10%～20%之間，這些土壤均來自旗山地區尚未發生黃葉病的蕉園。另外厚膜胞子發芽率在30%～60%的土壤樣品共有8個，這些地區黃葉病發生有三種不同情形，即(i) 尚未發病蕉園，例如旗山、里港和楠西的蕉園，(ii) 發病嚴重地區，大部份蕉園已廢耕而僅存的少數蕉園，例如新園和林邊的蕉園，和(iii) 每年均有發病，但病勢進緩慢的蕉園，例如大寮地區蕉園，其他57個土壤樣品的厚膜胞子發芽率均達80%以上[3]。這些資料顯示即使在發病嚴重的蕉區，土壤並不均勻，可能還有少數土壤能抑制病菌的感染，或是減少蕉園發病率。

利用組織培養小蕉苗作接種試驗，蕉苗的發病率與厚膜胞子在土壤平板上的發芽率呈顯著相關[3]，然其迴歸方程式所估計發病率的準確性仍有相當的變異，亦即部份半抑菌土並非抑病土，不過若是強抑菌土，即使土壤中病原菌密度改變，它們還是表現出抑病性（表一）。

表一、土壤含不同量厚膜胞子對組織培養蕉苗黃葉病發生之影響

Table 1. Fusarium wilt of banana plantlets planted in different soils infected with chlamydospores of *Fusarium oxysporum* f. sp. *cubense*

Inoculum density (Chlamydospore/g soil)	Disease incidence (%)		
	Sui-1	Chuan-2	TBRI
5×10^4	20.0 a[1)]	25.0 a	57.1 b
5×10^3	25.0 a	12.5 a	76.9 b
5×10^2	21.4 ab	17.7 a	28.6 b

1) Data followed by the same letter at each inoculum density are not significantly different ($p = 0.05$) according to Duncan's multiple range test.

抑病土對病原菌存活和厚膜胞子形成之影響

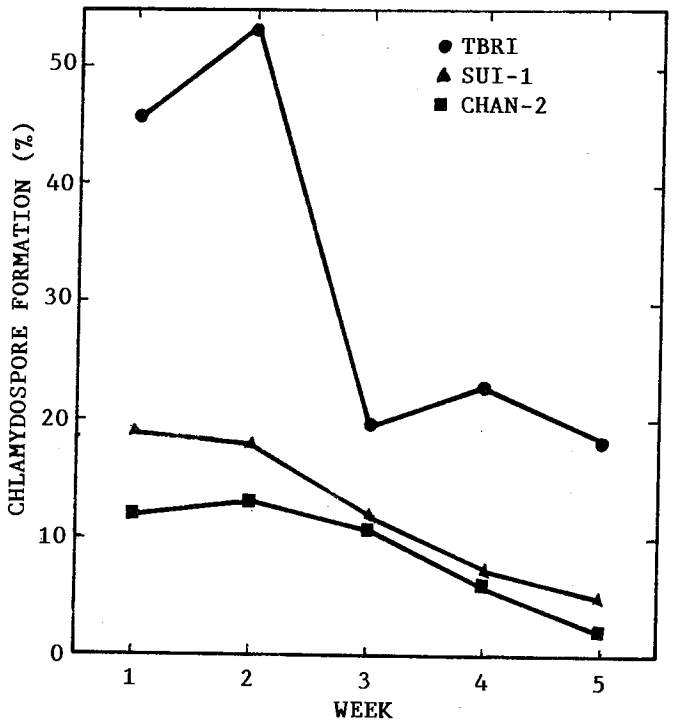
在抑病土中加入病原菌的厚膜胞子，初期病原菌的族群密度有增加的現象，而其增加量比導病土爲少，但隨著時間增加，抑病土中的病原菌密度下降很快，經過四個月後，病原菌祇剩1%～6%存活，而導病土中仍有10%～30%存活，到了第五個月，就無法在抑病土中偵測到病原菌，但導病土中還剩下10%病原菌存活[4]。將大胞子滴上土壤平板上，經過一週後，可見新的厚膜胞子形成，但在抑病土上的厚膜胞子形成量遠比導病土爲少（圖一）[4]。觀察土壤平板上菌絲溶解情形，抑病土亦較易促進菌絲溶解。

抑病土之土壤理化性質

分析15個土壤樣品的鈣、鎂、鉀、磷與有機質含量，發現祇有鈣含量與厚膜胞子發芽呈負相關（圖二），至於鎂、鉀、磷和有機質含量與土壤抑菌性無關。又分析20個土壤樣品中的砂粒、矽粒與粘粒含量，亦與土壤抑菌性無關，但是土壤pH值卻與抑菌性呈顯著的正相關（圖三）[4]。

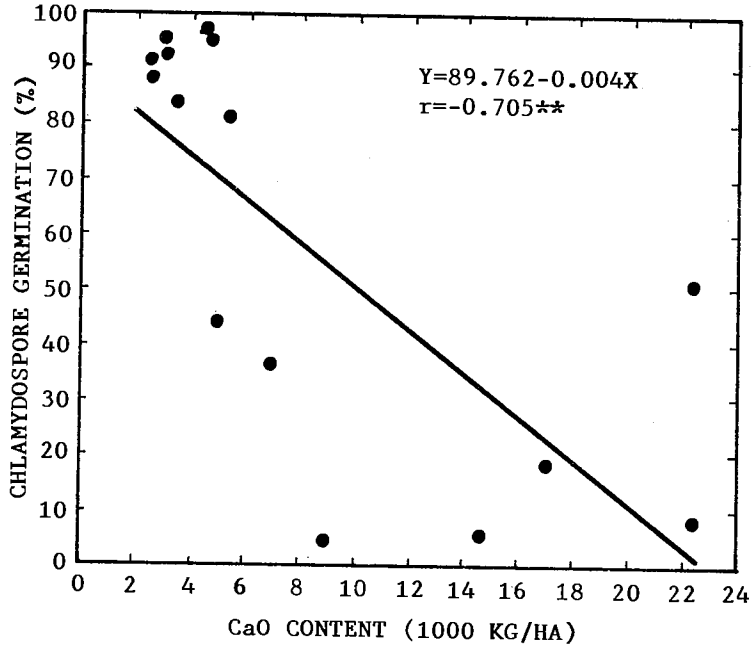
抑病土之微生物特性

分析12個蕉園土壤樣品，微生物族群變化很大，經統計分析後，祇有放射菌的族群密度與厚膜胞子發芽有顯著相關，至於細菌和眞菌的族群密度則與厚膜胞子發芽無顯著相關[4]。



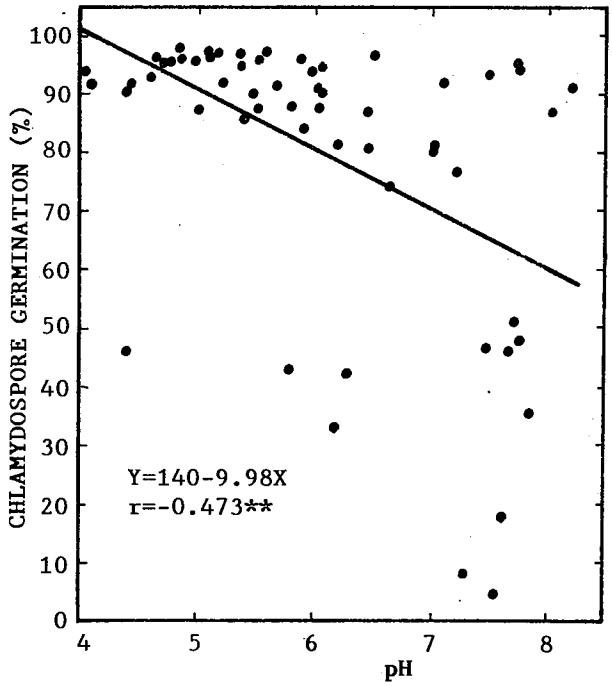
圖一、香蕉黃葉病菌在不同土壤中形成厚膜胞子之比較

Fig 1. Chlamydospore formation from macroconidium of *Fusarium oxysporum* f. sp. *cubense* in soils. TBRI is conducive soil, SUI-1 and CHAN-2 are suppressive soils.



圖二、香蕉黃葉病菌厚膜胞子發芽與土壤鈣含量之關係

Fig 2. The relationship between chlamydospore germination of *Fusarium oxysporum* f. sp. *cubense* and calcium content in soils.



圖三、香蕉黃葉病菌厚膜胞子發芽與土壤 pH 值之關係

Fig 3. The relationship between chlamydospore germination of *Fusarium oxysporum* f. sp. *cubense* and soil pH.

但若祇比較旗山地區的强抑病土與香蕉研究所的導病土，則放射菌族群密度的差異並不很明顯。

定期採集根圈土壤測定細菌、眞菌和放射菌的族群密度，經連續 10 個月的調查，發現抑病土與導病土的微生物族群並無顯著差異，各土壤中微生物族群變化很大[5]，主要可能決定於各蕉園管理方法與蕉株生長狀況而不同。抑病土與導病土的香蕉根圈都有拮抗菌存在，由抑病土和導病土所分離的微生物與病原菌作對峙培養，兩類土壤所獲得的拮抗眞菌與放射菌均無明顯差異，而抑病土所獲得的拮抗細菌比例卻反較導病土爲低（表二）。這些在培養基上具有拮抗作用的微生物作接種試驗，由抑病土獲得的 37 株拮抗菌中，有 9 株具防病效果，佔 24.3%；而由導病土所獲得的 75 株中，有 19 株具防病效果，佔 25.3%（表三），彼此間並無顯著差異[5]。此三類拮抗菌中，具防病效果的拮抗眞菌比例最高。

表二、抑病土與導病土香蕉根圈微生物對香蕉黃葉病菌生理小種 -4 在馬鈴薯瓊脂培養基上拮抗作用之比較

Table 2. Antagonism test of banana rhizosphere microorganisms from suppressive- and conducive- soil against *Fusarium oxysporum* f. sp. *cubense* race 4

Microorganism	Suppressive soil		Conducive soil	
	# test	# antagonist	# test	# antagonist
Bacterium	426	5 (1.2%)	429	27 (6.3%)
Fungus	282	22 (7.8%)	297	25 (8.4%)
Actinomycetes	220	8 (3.6%)	142	5 (3.5%)

表三、抑病土與導病土香蕉根圈分離的拮抗的對香蕉黃葉病防治效果之比較

Table 3. Comparison of antagonists from banana rhizosphere of suppressive- and conducive-soil for controlling fusarial wilt of banana plantlets in pot test

Microorganism	Suppressive soil		Conducive soil	
	# test	# effective	# test	# effective
Bacterium	5	0 (0%)	25	27 (24%)
Fungus	27	8 (29.6%)	33	25 (33.3%)
Actinomycetes	5	1 (20%)	17	5 (11.8%)
Total	37	9 (24.3%)	75	19 (25.3%)

土壤處理對抑病土之影響

無論抑菌土或半抑菌土經蒸氣消毒後，抑制厚膜胞子發芽的能力消失，但放置7天後，又稍爲恢復抑菌性[4]，例如未消毒抑病土（寺-2），厚膜胞子發芽率爲3.5%，但經蒸氣消毒後，發芽率增加爲89.1%，而放置7天後，又稍爲降至77.1%。若在抑病土中添加抗生物質，亦會影響其抑菌性[4]。每克土壤添加rose bengal 330 μg或streptomycin 6667 μg，均會顯著提高厚膜胞子的發芽率，降低其抑菌性。在土壤添加glucose-asparagine營養液後，立即測定厚膜胞子發芽，發現隨著營養濃度增加而抑菌性降低，但經7天後，其抑菌性卻隨著營養液濃度增加而顯著增加（表四）。測定加入營養液土壤的微生物變化情形，依抑病土來源不同而有差異，每克土壤加入30 μg營養液時，細菌族群大量增加，放射菌稍爲減少，而眞菌起初增加，但7天後又減少；加入300與3000 μg營養液時，細菌與放射菌顯著增加，但眞菌族群變化不大[4]。一般而言，抑病土相當穩定，經風乾在室溫儲存一年後，雖然抑菌性大爲降低，但經預溼處理3天抑菌性又逐漸恢復。這些結果顯示微生物因子在抑病土的機制中扮演著重要角色。

由於統計分析結果顯示土壤鈣含量和pH值均與抑菌性有顯著相關，若在導病土中加入鈣化物或改變其pH值，是否會影響其抑病性？試驗結果顯示，導病土加入$CaCl_2$，厚膜胞子發芽率會隨著鈣濃度增加而減少[2]，例如未添加$CaCl_2$之導病土，厚膜胞子發芽率爲87%，但添加8000 ppm鈣時，發芽率降爲60%。另外不同鈣化物對厚膜胞子發芽的抑制效果差異很大（表五），以$CaCO_3$的效果最好，$CaSO_4$與$Ca_3(PO_4)_2$次之，$CaCl_2$、$Ca(OH)_2$及$Ca(NO_3)_2$的效果較差。在這些鈣化物中，$Ca(OH)_2$和$CaCO_3$會顯著提高土壤pH值，而$CaCl_2$、$CaSO_4$、$Ca_3(PO_4)_2$和$Ca(NO_3)_2$對土壤pH值影響很小。又將抑病土的pH由7.5調低爲5.0時，會促進厚膜胞子發芽，稍爲降低其抑菌性，但相反的，將導病土的pH由5.0調整爲7.5，對厚膜胞子發芽影響很小。這些結果顯示鈣離子亦在抑病土的機制上扮演著重要的角色，但土壤pH值本身似乎不重要，不過它可能影響土壤微生物的活性或鈣離子的可利用性，從而影響土壤的抑病性。

抑病土之誘發

抑病土和導病土依不同比例混合後，均會降低厚膜胞子的發芽率，其抑菌效果會隨著抑病土量增加而增加。而且無論抑病土或導病土經蒸氣消毒後，再加入抑病土，均能誘發出部份抑菌性。加入導病土於蒸氣消毒的導病土無此作用，而加入於消毒的抑病土，則會稍降低厚膜胞子發芽[2]。

拮抗細菌加入蒸氣消毒或未消毒的導病土，可以顯著降低厚膜胞子發芽，而加入無拮抗作用的細菌亦會降低厚膜胞子發芽，但效果較差。加入拮抗放射菌亦可誘發導病土的抑菌性，但在經蒸氣消毒的土壤效果較好。無論是否具有拮抗作用，眞菌加入導病土都不能顯著抑制厚膜胞子發芽[2]。

表四、添加營養對抑病土抑制香蕉黃葉病菌厚膜胞子發芽之影響

Table 4. Effect of addition of nutrient on chlamydospore germination of *Fusarium oxysporum* f. sp. *cubense* on suppressive soils

Glucose-asparagine (μg/g soil)	Germination (%)			
	Sui-1 soil		Chan-2 soil	
	0 day	7 day	0 day	7 day
0	16.8 a[1)]	28.6 c	7.8 a	30.6 c
30	7.1 a	19.7 b	5.8 a	16.4 b
300	21.3 a	5.9 a	32.5 b	10.4 ab
3000	69.6 b	4.0 a	53.0 c	3.7 a

1) Numbers in each column followed by the same letter are not significantly different at p = 0.01 according to Duncan's multiple range test.

表五、不同鈣化物對香蕉黃葉病菌原膜胞子發芽之影響

Table 5. Effect of calcium from various sources on chlamydospore germination of *Fusarium oxysporum* f. sp. *cubense*

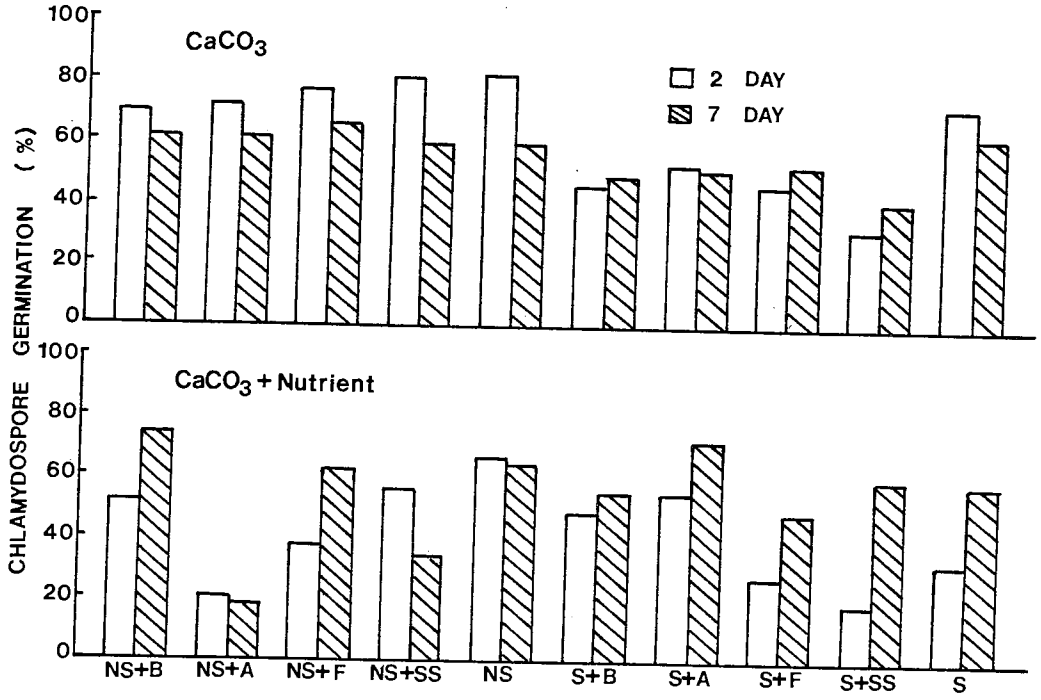
Treatment	pH	Germination (%)	
		2 day	7 day
$CaCl_2$	5.4	78.4 cd[a)]	88.6 bc
$Ca(OH)_2$	10.4	90.4 d	84.4 bc
$CaCO_3$	7.5	42.1 a	43.9 a
$CaCO_4$	5.8	67.8 bc	79.6 b
$Ca_3(PO_4)_2$	5.9	60.0 b	77.1 b
$Ca_3(NO_3)_2$	5.4	86.3 d	82.8 bc
CK	5.7	90.5 d	90.6 c

a) Numbers in each column followed by the same letter are not significantly different at p = 0.01 according to Duncan's multiple range test.

一般而言，誘發抑病土的效果，在蒸氣消毒的土壤比不消毒土壤爲佳（圖四）。加入 $CaCO_3$ 土壤經蒸氣消毒後，再加入各種微生物或1%抑病土，其抑病效果比單獨加入 $CaCO_3$ 爲佳，但在加入 $CaCO_3$ 和 glucose-asparagine 混合營養液的導病土經蒸氣消毒後，再加入微生物或1%抑病土，則與單獨加入 $CaCO_3$ 和營養液的效果類似。相反的，在不經蒸氣消毒的導病土，添加 $CaCO_3$ 後，再加入微生物或1%抑病土，其抑菌效果並不比單獨加入 $CaCO_3$ 爲佳，但在土壤同時添加 $CaCO_3$ 和營養液後、再加入放射菌或1%抑病土，則顯著增加抑菌效果，但加入眞菌或細菌卻與單獨加入 $CaCO_3$ 和營養液者無明顯差異。又由於土壤來源不同，相同處理之誘發抑菌效果亦不一致，而以導病土中同時加入 $CaCO_3$，營養液和放射菌的效果最好。

溫室試驗中，小蕉苗以拮抗菌作浸根處理後，先假植一個月，再移植於混合碳酸鈣與（或）苜蓿的病土，均會降低發病，而以拮抗菌與碳酸鈣綜合處理的效果較好，另外僅添加碳酸鈣者亦會降低發病。若在病土中同時添加拮抗菌、碳酸鈣和 S-H 混合物，而小蕉苗不加以處理，則其防病效果不穩定，其變異頗大。

在田間試驗，若祇以拮抗菌處理小蕉苗，再種於病田，雖然會延緩發病，但經8個月後，似乎沒有防病效果；若土壤中添加石灰或雞糞，小蕉苗種植4個月後，會降低發病（表六），但在沒有拮抗菌處理下，石灰亦能有效降低發病。



圖四、導病土之抑菌性誘發

Fig 4. Induction of suppressiveness for conducive soil. NS = None steamed soil, S = Steamed soil, SS = 1% suppressive soil, B = Bacteria, A = Actinomyctes, F = Fungi.

表六、以拮抗菌和土壤添加物綜合防治香蕉黃葉病田間試驗

Table 6. Integrated control of banana fusarial wilt with antagonists and soil amendment in field test 4 months after planting[1)]

Antagoist[2)]	Liming		Chicken manure		Control	
	Plant no.	Disease (%)	Plant no.	Disease (%)	Plant no.	Disease (%)
A	12	0.0	13	30.8	12	33.3
B	12	0.0	13	15.4	13	30.8
D	13	23.1	12	16.8	14	42.9
G-9	12	16.7	12	8.3	14	50.0
CF303	12	0.0	13	23.1	14	14.3
CK	11	9.1	11	18.2	14	21.4

1) Banana plantlets were planted in diseased field on July 6, 1989.

2) A = CB101 + SF200 + CF303; B = CB705 + SF501 + SF600; D = CB101 + CB602 + CB705; G-9 = *Gliocladium virens*; CF303 = *Trichoderma viride*.

結　論

本省中南部蕉區抑病土存在的比例很低，但半抑病土則普遍存在。抑病土能抑制病原菌厚膜胞子發芽和新厚膜胞子形成，並且能加速菌絲溶解，因此能抑制黃葉病的發生。此抑病土的抑病機制可能爲土壤鈣離子與非專一性微生物交感作用的綜合結果。一般而言，添加碳酸鈣、營養液和微生物於消毒的導病土比未消毒的導病土容易誘發抑菌性。在田間試驗顯示，祇以拮抗菌處理小蕉苗並無防病效果，必須配合土壤添加石灰或有機質，方能顯出防病效果，而祇有土壤添加石灰亦有降低發病的效果。

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ABSTRACT

Chuang, T, Y. 1991. **Suppressive soil of banana fusarium wilt in Taiwan.** Plant Prot. Bull. 33:133-141. (Department of Plant Pathology and Entomology, National Taiwan University, Taiwan, R.O.C.)

There was a positive correlation between chlamydospore germination on soil surface and infection rate of banana plantlets among 10 soils tested. Among 69 soil sam-

ples collected from central and southern Taiwan tested, only few soils were pathogen-suppressive. The chlamydospore germination and new chlamydospore formation were inhibited significantly in suppressive soil. Mycelial lysis was also enhanced in suppressive soil. The pathogen survived longer in conducive soil than in suppressive soil. Analysis of soil samples revealed that chlamydospore germination on soil was inversely correlated with pH and Ca content, but it was not correlated with Mg, K, P, organic matter content of soil texture. A negative correlationship between chlamydospore germination and population of actinomycetes but not bacteria and fungi, in soil, was found. Steaming completely nullified the inhibitory effect of suppressive soils, but the suppressiveness was somewhat restored when the soils were exposed to the air for 7 days. Addition of rose bengal or streptomycin to suppressive soils greatly decreased their inhibitory effects. Addition of glucose-asparagine solution at the concentration of 300 and 3000 ppm to the suppressive soils also decreased the suppressiveness at the beginning, but the suppressiveness was greatly enhanced 7 days after nutrient amendment. The suppresiveness of conducive soil was increased after adding antagonistic bacteria and actinomycetes, but not fungi, into soil. The addition of $CaCO_3$ or $CaCO_3$ mixed with glucose-asparagine solution followed by microorganisms or 1% suppressive soil into conducive soil resulted in increasing suppressiveness. The efficacy of induction of suppressiveness in steamed soil was better than in none steamed soil.

(Key words: Fusarium wilt of banana, *Fusarium oxysporum* f. sp. *cubense*, suppressive soil)

土壤病原生態與防治研討會專刊 142~147, 1991

台灣土傳性疫病之防治及抑病土壤

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摘　要

安寶貞、柯文雄、高清文 1991 台灣土傳性疫病之防治及抑病土壤　植保會刊 33:142～147

經測定土壤對胞囊發芽力的影響，發現柑桔疫病菌（*Phytophthora parasitica, P. palmivora*），及甜椒疫病菌（*P. capsici*）之抑菌土壤在本省西部的分佈非常普遍，但並不一定十分均勻的分佈在同一塊田土中，有些抑菌土壤樣品之週邊土壤並不抑菌。所有已發現之 *P. capsici* 抑菌土壤均爲 *P. parasitica* 及 *P. palmivora* 之抑菌土壤，但反之並不亦然。抑菌土壤與地上部耕作物之種類，土壤之質地、顏色似無關係。大部分抑菌土壤之酸鹼值均在 pH 5.0 以下，但酸鹼值在 pH 5.0 以下之土壤並不一定是抑菌土壤。大部分抑菌土壤經 100℃蒸氣處理 15 分鐘後，仍具抑菌性。但是抑菌土壤經 KOH 調節酸鹼值在 pH 5.0～8.0 時，即失去抑菌性。二鹽基或三鹽基之單價陽離子磷酸鹽類有抑制疫病菌胞囊發芽之能力。

（關鍵字：土壤傳播，疫病，疫病菌，抑病土壤）

緒　言

台灣位於熱帶及亞熱帶，氣候高溫多溼，冬季又乏低溫來降低土壤中病原菌之密度，因而土壤病害十分猖獗。土壤傳播性疫病菌在本省之分佈非常普遍[11,21]，重要者包括 *Phytophthora parasitica, P. palmivora, P. capsici, P. cinnamomi, P. citrophthora, P. citricola, P. drechsleri, P. cryptogea* 及 *P. colocasiae*。重要之寄主包括柑桔[1,13]、木瓜[10]、鳳梨[9]、百香果[3,6]、酪梨、甜椒[5]、胡瓜[8,28]、茄子[4]、芋[14]、草莓[22]，多種花卉及觀賞植物[2,7,16,17]。

目前常用來防治作物疫病之方法，以栽培抗病品種[31]及施用化學藥劑[33]爲主。然而在本省，許多重要作物的疫病均無適當之防治推廣藥劑[12]。此外，用農藥來防治根部病害較防治葉部病害困難，乃因土壤結構、理化性質及微生物相較複雜，農藥容易被吸附或分解而無法發揮效力。同時農藥殘毒對環境造成之污染，亦爲今日之嚴重問題。故而，多年來許多植物病理學家均致力於疫病的其它防治方法之開發利用[32]，至今已有成功之實例。例如土壤填加有機質，利用抑病土壤，及其它之生物防治與耕作防治等。茲將近年來一些有關本省重要作物疫病防治之試驗結果報告於下：

化學防治（Chemical controls）

依據紀載[31]，對疫病有預防或治療效果之

農藥包括銅劑、硫磺劑、抗生素、混合藥劑及一些新開發的系統性藥劑，例如滅達樂（Metalaxyl）、Prothiocarb、福賽得（Fosetyl-A1）等。最近國外亦發現亞磷酸對酪梨根腐病有防治效果[18]。在本省正式登記於植物保護手冊，用於防治土傳疫病之藥劑亦不多[12]，包括依得利（Etridiazole）、滅達樂、福賽得、銅鋅錳乃浦（Mancozeb + oxychoride）、鋅乃浦（Zineb）、免得爛＋免克寧（Metiram + Vinclozolin）、普拔克（Propamocarb hydrochloride）及快得寧（Oxinecopper），分別用以防治胡瓜、甜椒、番茄幼苗、茄子果實、鳳梨、草莓果實、及蘭花的疫病。林及吳氏[28]亦報告鋅錳滅達樂（Redomil-MZ）對胡瓜疫病有良好之防治效果。而柑桔根腐病及其它重要作物（例如木瓜、百香果、酪梨、芋、多種花卉及觀賞植物）之疫病，目前均無防治藥劑。

近來利用稀釋平板法，將20餘種化學藥劑加入5% CV-8瓊脂（5% CV-8 agar，含5% V-8 juice，0.2% $CaCO_3$，以上兩者經1500 rpm離心5 min，2% Bacto agar）或5% CV-8蔬菜汁中，以測定各化學藥劑對疫病菌 *P. parasitica*、*P. palmivora* 及 *P. capsici* 之胞囊發芽及菌絲生長之抑制能力。結果以10 ppm之滅達樂、鋅錳乃浦（Mancozeb）、錳乃浦（Maneb）、甲基鋅乃浦（Propineb）、氧化亞銅（Cuprous oxide）、快得寧、腈硫醌銅、鋅錳波爾多、鋅錳賽得、鋅錳克絕、嘉賜銅、銅錳乃浦、1000 ppm之亞磷酸，及四—四式波爾多液對疫病菌之胞囊發芽有完全的抑制作用。而10 ppm之滅達樂、依得利、鋅錳乃浦、錳乃浦、甲基鋅乃浦、氧化亞銅、腈硫醌銅、鋅錳波爾多、鋅錳賽得、鋅錳克絕、嘉賜銅、100 ppm之亞磷酸，及四—四式波爾多液則對疫病菌之菌絲生長有抑制作用。此外，將1%或0.5%之二鹽基或三鹽基之單價陽離子磷酸鹽（例如 Na_3PO_4、Na_2HPO_4、K_3PO_4、K_2HPO_4、$(NH_4)_3PO_4$及$(NH_4)_2HPO_4$）或亞磷酸鹽填加於土壤中一至二星期，亦能降低疫病菌 *P. palmivora* 及 *P. capsici* 之胞囊發芽率（低於20%）。反之，雙價陽離子磷酸鹽（鈣或鎂之磷酸鹽）及單鹽基之磷酸鹽則無抑菌效果（未發表）。

生物防治及栽培防治（Biological and cultural controls）

利用非農藥的方法來直接增強寄主之抗病性或降低土壤中疫病菌之密度或致病力，或改變土壤環境來間接影響寄主與疫病菌之相互關係，亦能達到防治作物疫病之目的[32]。著名之例包括：柯氏[23]利用木瓜株齡對 *P. palmivora* 抗感病性反應之差異，有效的以處女土（Virgin soil）解決了夏威夷因根腐病引起之木瓜重植問題。在澳洲，Malajczak[30]報告利用填加有機質於土壤，能有效的防治由 *P. cinnamomi* 引起之酪梨及尤佳利根腐病。目前能實際應用於疫病之生物防治方法仍然很少，大部分尚在研究階段。

本省在疫病方面的生物及栽培防治研究較少，呂及高氏[4]報告利用覆蓋法可以防治由 *P. capsici* 及 *P. parasitica* 引起之茄子果實疫病，且以稻草覆蓋的效果最佳，能阻斷初次感染原與茄果之接觸。林及吳氏[28]發現經兩期水稻輪作的胡瓜病田中已無胡瓜疫病菌。而植物保護手冊中則說明，防治可攜帶疫病菌之蝸牛，可以降低木瓜果實疫病的感染率[12]。其它，如注意種苗、田間衛生、灌溉、排水及施肥問題，以減少作物疫病之發生，多記錄在一般推廣手冊中，較少有正式之試驗報告。

將接種立枯病原之酸桔幼苗根系接種柑桔疫病菌 *P. parasitica*，發現細根被疫病菌感染之百分率增高[15]。在國外亦有因複合感染而引起疫病發生，或造成疫病猖獗之實例[32]，此亦爲防治疫病時應注意的問題。

抑病土壤（Suppressive soils）

有時在感病品種、病原菌及適合發病之氣候三者均同時存在的情況下，病害並不發生[32]。偶爾亦會發現生長在某些地區的植物，其發病程度較臨近地區者爲低。在澳州，發現土壤中的生物及非生物性因子均與一些抑制 *P. cinnamomi* 的土壤有關[18,19]，抑病的森林土壤中，有機質、氮素、及可交換性鈣離子的含量均較導病土壤中的含量爲高。柯及Nishijima[27]發

現夏威夷存在 *P. capsici* 之抑菌土壤，抑制番茄幼苗疫病之發生。其抑病土壤的抑病因子爲非生物性，耐高溫且爲非水溶性。盧及莊氏[29]亦在本省發現數個抑制 *P. capsici* 及其引起之番茄幼苗疫病的抑病土壤，並發現抑病土壤的抑病性與土壤中可交換性鋁離子的含量正相關，與土壤之酸鹼值負相關。

近來吾人亦從不同地點，不同耕作區（包括無耕作區）採集土壤樣品。採集土壤之酸鹼值在 pH 3.0～8.9 之間，土壤質地從砂質土到黏質土，土壤顏色包括紅、黃、褐至黑色。地上部之作物種類包括果樹、旱作、水稻、蔬菜、花卉及無耕作地等。利用柯及何氏發展之方法[26]，測定疫病菌胞囊在各土壤樣品表面上的發芽率，以調查本省的抑菌及抑病土壤。胞囊發芽率在 20% 以下的被視爲抑菌土，90% 以上者爲導病土壤。400 克之抑菌土壤並混和 10 ml 的 *P. capsici* 胞囊懸浮液（每克土壤含 250 個胞囊），種植經催芽處理之甜椒種子，定期調查幼苗的發病率，以明瞭抑菌土壤之抑病性。結果至今共採集 466 處土壤樣品，其中分別有 46、86 及 77 個土壤對甜椒疫病菌 *P. capsici* 及柑桔疫病菌 *P. palmivora*、*P. parasitica* 有抑制性；而 40, 12 及 6 個土壤分別可以維持上述三疫病菌之胞囊發芽率在 90% 以上。*P. capsici* 的胞囊在大部分土壤（302 個土壤，64.8%）上之發芽率約在 60～90%。而 *P. palmivora* 及 *P. parasitica* 的胞囊在大部分土壤上之發芽率則在 60～80%。

所有 *P. capsici* 的抑菌土壤，均爲柑桔疫病菌 *Phytophthora parasitica* 及 *P. palmivora* 的抑菌土壤，但反之並不亦然。三種疫病菌的胞囊在各個土壤樣本上之發芽率大約正相關。抑菌土壤在田間之分佈並不一定十分均勻，在 46 個抑菌土壤周圍再採集之土壤中即有 10 個土壤不具抑制 *P. capaici* 胞囊發芽之能力。

在測定之 30 個具有抑制 *P. capaici* 胞囊發芽之能力的土壤樣品中，對甜椒疫病亦同樣具抑病性，但僅有 4 個抑菌土壤（採集自嘉義太保之玉米田及辣椒田，蒜頭之辣椒田，及斗南之甘蔗田）在填加疫病菌後，植株生育良好，且發病輕微。甜椒幼苗在其餘的土壤中生育較差。

所有 *P. capsici* 的抑菌土壤之酸鹼值均在 pH 5.0 以下，但低酸鹼值的土壤並不一定抑菌。抑菌土壤與地上部之耕作物無關，與土壤之色澤、質地亦無關。抑菌土壤之地上部耕作物包括辣椒、柑桔、水稻、雜糧、蔬菜、花卉、茶樹、特用作物、多種其它果樹及無耕作區；土壤之顏色則從土黃色、紅色、灰色而至褐色、深黑色；土壤質地大部分爲壤土、黏質壤土、或黏土。抑菌土壤經 100℃ 高溫蒸氣處理 15 min 後，大部分土壤仍保有強烈之抑菌性。而 5 個胞囊發芽率在 90% 以上之土壤，經高溫處理後，仍能使胞囊發芽力維持在 90% 以上。將 5 處抑菌土壤之酸鹼值以 1 N KOH 調節至 pH 5.0～10.0。結果在 pH 5.0～8.0 之範圍內，絕大部分抑菌土壤均失去抑菌能力；有些抑菌土壤在此 pH 值範圍內，甚而能使胞囊發芽率上升至 90% 以上。抑菌土壤在 pH 值 9.0 或 10.0 時又恢復其抑菌力。供試之導病土壤（採自嘉義之甘薯田，土壤之酸鹼值爲 pH 6.5）之酸鹼值調節至 pH 7.0～9.0 時，仍能維持疫病菌之胞囊發芽率在 90% 左右；但在酸鹼值上升至 pH 10.0 時，胞囊發芽率亦顯著下降（以上均爲未發表資料）。

結　論

二鹽基或三鹽基之單價陽離子磷酸鹽類有抑制疫病菌胞囊發芽之能力，在國內外尚無類似的報告發表，其原因尚待繼續探討。

抑菌土壤在田間之分佈十分普遍，約佔調查土壤樣品之 10% 左右。但同一田地之土壤抑菌性並不一定十分均勻，在重複採集之抑菌土壤中，即有多處土壤之週邊土壤並不抑菌。抑菌土壤與地上部作物種類，土壤之質地、顏色似無重要關係，但與酸鹼值有關。目前已發現之 *P. capsici* 抑菌土壤，其酸鹼值均在 pH 5.0 以下；大部份 *P. parasitica* 與 *P. palmivora* 之抑菌土壤的酸鹼值亦在 pH 5.0 以下，但酸鹼值在 pH 5.0 以下之土壤並不完全抑菌。當抑菌土壤之酸鹼值調高至 pH 5.0～9.0，即失去抑菌性，顯示大部分抑菌土壤之抑菌因子在酸鹼值 pH 5.0 以下，才有抑菌作用，但酸鹼值

並非導致土壤抑菌之主因。又抑菌土壤在100℃高溫處理15 min後，仍保有相當之抑菌能力，顯示抑菌因子可能與非生物性因子有關。在此試驗中，雖然採集到多處抑菌土壤，但大部份抑菌土壤亦抑制甜椒幼苗之生育或種子發芽，僅有四處抑菌土壤能維持甜椒幼苗之良好生長。三種疫病菌 *P. capsici*、*P. palmivora* 及 *P. parasitica* 的胞囊在各個土壤樣本上之發芽率大約正相關。且所有 *P. capsici* 的抑菌土壤，均爲其它兩疫病菌的抑菌土壤，顯示此種抑菌土之抑菌性對此三種之疫病菌並不具有專一性。

吾人調查到的疫病菌的抑病土壤，其特性與柯及 Nishijima[27]氏、及盧及莊氏[29]發現的抑制 *P. capsici* 的抑病土壤的特性甚相似，均與非生物性因子有關。但各抑菌土壤之抑菌範圍與抑制因子，仍待詳加探討，以明瞭其機制。利用測定土壤之抑菌性來篩選抑病土壤，可能會漏失一些抑病但不抑菌的土壤，但此方法能在較短時間內篩選較多之土壤樣品。

填加營養分或其它物質於土壤，能改變土壤中的微生物相[24]，進而改變土壤中寄主根系與病原菌的相互關係。利用填加有機質於土壤，已有防治疫病成功之實例[30]。因此尋求適合之有機質及微生物，用於填加土壤，以達防治作物疫病的功效，亦爲今後試驗之目標。

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ABSTRACT

Ann, P. J.[1], Ko, W. H.[2] and Kao, C. W.[3] 1990. Disease controls of soil-borne *Phytophthora* and their suppressive soils in Taiwan. Plant Prot. Bull. 33:142-147 (1. Chia-yi Agricultural Experiment Station, Chia-yi, Taiwan, R.O.C., 2. Department of Plant Pathology, University of Hawaii, Hilo, Hawaii, U.S.A., 3. Council of Agriculture, Taipei, Taiwan, R.O.C.)

When spore germination was used to assay pathogen suppression, soils suppressive to *Phytophthora parasitica, P. palmivora* and *P. capsici* were found to be widely distributed in the western Taiwan. Soil sample collected from the same general areas showed considerable variation in pathogen suppression. These three species of *Phytophthora* behaved similarly in regard to sporangial germination in most of the soils tested. The degree of pathogen suppression was not correlated with soil texture, soil color or vegetation. All of the soils suppressive to *P. capsici* and most soils suppressive to *P. palmivora* and *P. parasitica* were with pH value lower than pH 5.0. However, some soils with pH lower than 4.0 still supported more than 80% germination of sporangia of all three *Phytophthora* species. When the pH was adjusted to 6-8 the suppressive soils tested became conducive. Most suppressive soils remained suppressive to *Phytophthora* after being steamed at 100℃ for 15 min. The conducive soil became suppressive to sporangial germination when it was amended with dibasic or tribasic phosphate monovalent cation salts.

(Key words: soil-borne, Phytophthora diseases, *Phytophthora* spp., suppressive soils)

綜 合 討 論

杜瑞章問：

做生物防治以前，是否應先考慮抗病品種的應用？

吳文希答：

研討這方面的問題確實應定重點，並做個組合，以整合有限人力做些突破性的工作。

黃新川答：

(1)傳統雜交育種遇到困難時，建議試用組織培養突破瓶頸。

(2)做拮抗菌的研究，在試驗設計方面，建議對照組也要添加另外的微生物，才能確實評估它的效果。

孫守恭問：

(1)首先就土壤傳播性病害方面，建議能否成立一個研究小組？

(2)請農林廳或其他機構，推廣應用研討會的實際成果？

范國洋答：

(1)植保學會、植病學會今後類似這麼好的主題要召開，我們非常樂意來贊助。

(2)有關生物防治技術，請兩個學會或農試所植病系彙編成手冊，交農林廳付印，廣爲分發。

吳文希問：

將來拮抗菌之大量生產，在法規上的問題，如何解決。

高清文答：

目前農委會已在草擬及改進相關條文。

劉顯達答：

將來拮抗菌大量生產，應該能商品化。目前應解決的問題有：

(1)微生物專利。

(2)微生物製劑的規範等法規之修定與制定。

呂理燊問：

土壤病害很多基本問題，建議能否結合不同領域的人，包括土壤學者，共同從各方面來做，有效解決問題。但這要農委會來協調。

高清文答：

將在農委會裡成立跨科系的合作計畫。

杜金池答：

科技整合共同解決問題，農試所已朝著這方面在做，可以提出來供大家參考。

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（按筆劃排序）

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