

果樹炭疽病菌之分子鑑定及其對殺菌劑之感受性

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摘要

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Colletotrichum spp. 引起的炭疽病是臺灣地區普遍且嚴重的果樹病害，也是影響水果品質與產量的重要因子。本研究以分生孢子發芽及菌絲生長為指標，評估 12 株芒果炭疽病菌 (代表殺菌劑主要使用對象) 與 12 株酪梨、香蕉、無花果、印度棗及草莓等 5 種水果類炭疽病菌 (代表殺菌劑少量使用對象)，對 33 種殺菌劑之感受性。供試之 24 株炭疽病菌以分生孢子形態及多重基因序列比對作菌種鑑定，結果顯示，芒果炭疽病菌計有 3 菌種，其中有 9 株 *C. asianum* Prihastuti，2 株 *C. siamense* Prihastuti 及 1 株 *C. scovillei* Damm。而其他 5 種果樹類炭疽病菌則分別有 3 株 *C. fructicola* Prihastuti、1 株 *C. musae* (Berk. & Curtis) Arx、5 株 *C. siamense*、1 株 *C. theobromicola* Delacr. 及 2 株 *C. tropicale* Rojas, Rehner & Samuels 計有 5 菌種。藥劑依田間使用濃度測試上述菌株結果發現，有效抑制炭疽病菌孢子發芽或菌絲生長的藥劑種類完全不同。能抑制全部供試菌株孢子發芽的藥劑有腈硫醃、腈硫克敏、扶吉胺、福賽快得寧、快得寧、保粒黴素 (甲)、保粒快得寧及腐絕快得寧等 8 種，能抑制絕大部分供試菌株孢子發芽的藥劑有克熱淨、鋅錳乃浦、免得爛及甲基鋅乃浦等 4 種。而能抑制全部或絕大部分供試菌株菌絲生長的藥劑僅有含撲克拉成分之撲克拉、撲克拉錳及貝芬撲克拉，而滅特座能抑制半數芒果菌株之菌絲生長。福賽快得寧可抑制半數芒果及半數其他果樹類菌株之生長，但單劑福賽得或快得寧均無此效。本研究顯示，果樹類炭疽病菌對其防治藥劑之感受性與菌株之寄主、菌種及施用藥劑是否為延伸使用等因子均無相關性。

關鍵詞：果樹、炭疽病菌、殺菌劑

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緒言

果樹炭疽病是由 *Colletotrichum* spp. 所引起，以果實為主要為害部位，氣候高溫潮濕有利本病之發生，常造成嚴重損失；而臺灣地處亞熱帶，屬炭疽病易發生地區⁽²⁶⁾。植物病原菌之鑑定與分類是植物病理學的基礎工作，準確鑑定病原菌方能針對病害採取適當的防治措施。*Colletotrichum* spp. 可用於鑑定與分類的形態特徵很少且差異不大，只能依據分生孢子 (conidia) 形態區分為數個複合種 (species complex)^(23, 34)。果樹炭疽病菌在分子生物學未應用於鑑定分類前常僅見 *C. gloeosporioides* (Penz.) Penz. & Sacc. 及 *C. acutatum* Simmonds 二個菌種 (species)，且以前者發生比例較高^(10, 30)，事實上它是代表兩個最常見的複合種。炭疽病菌種間 (inter-species) 分類與鑑定必須藉助分子生物學及生物資訊學之相關技術來釐清⁽²³⁾。*Colletotrichum* spp. 在種間鑑定上常用的基因序列包括核糖體核酸內轉錄間隔區 (internal transcribed spacer, ITS)，甘油醛-3-磷酸脫氫酶 (glyceraldehydes-3-phosphate dehydrogenase, GAPDH)、肌動蛋白 (actin, ACT)、微管蛋白 (β -tubulin-2, TUB2)、鈣調蛋白 (calmodulin, CAL)、幾丁質合成酶 (chitin synthase 1, CHS-1)、麩醯胺酸合成酶 (glutamine synthetase, GS) 及超氧化物歧化酶 (manganese-superoxide dismutase, SOD2) 等多種基因

(23, 33, 34, 37, 40, 45)。另一新的鑑定用基因序列 Apn2-Mat1-2 intergenic spacer (ApMat) 已導入 *Colletotrichum* spp. 之鑑定，且能替代前述多基因鑑定之結果^(47, 49)，本研究亦將之列入。綜合運用這些基因序列與標準菌株 (type culture) 之相同基因序列進行比對，可獲致可靠的鑑定結果^(34, 37, 40)。本研究使用源自不同果樹類之炭疽病菌菌株，其菌種鑑定將以比對其分生孢子形態及種間鑑定用基因序列為之。

果樹類炭疽病之防治主要依賴化學藥劑，藥毒所「植物保護資訊系統」即列有以藥劑為主的 24 種果樹類炭疽病防治方法⁽⁴⁾。由於各種果樹種植面積差異很大，產值亦不同，因而登記藥劑的種類因其市場需求而有數量上的差別。農藥的登記管理是依據民國 61 (1972) 年頒布並陸續修訂之「農藥管理法」來執行⁽²⁾，農藥登記依現行法規是採「單一作物單一害物」為登記原則，由廠商提出申請。廠商基於市場利潤考量，常以大面積作物或較嚴重病害做為登記標的，此為農藥用途範圍之主要使用 (major use)，但仍有小面積作物或主要作物之次要病害有用藥需求，此為農藥用途範圍之少量使用 (minor use)⁽⁶⁾。復依行政院農業委員會於民國 102 (2013) 年發布施行之「農藥田間試驗準則」，“主要使用”是指該殺菌劑經核准登記使用於主要作物及主要害物者，“少量使用”是指該殺菌劑經核准登記使用於少量作物或少量害物者，多指用於延伸使用範圍之作物⁽²⁾。而所謂延伸使用是指擴大一種藥

劑之使用範圍於同一 (類) 病原菌的其他受害作物 (跨作物) 或不同種 (科) 的病原菌 (跨害物), 目的在使農藥的應用能滿足少量使用之需求⁽⁶⁾。農藥登記使用既有此兩種樣態, 其對病害之防治效果是否有別, 常引起農民的疑慮, 值得研究人員運用科學方法進行有系統的藥效評估, 除為農民釋疑並可作為改進農藥登記制度的參考。芒果 (*Mangifera indica* L.) 是臺灣重要果樹, 栽培面積達一萬六千公頃⁽³⁾, 且曾名列四大外銷旗艦農產品之一。因而果樹炭疽病用藥均優先登記於芒果, 使芒果炭疽病可用藥劑種類為各種果樹類之冠, 可視為果樹類炭疽病主要使用的代表作物⁽⁴⁾。酪梨 (*Persea Americana* Mill.)、香蕉 (*Musa acuminata* Colla)、無花果 (*Ficus carica* L.)、印度棗 (*Zizyphus mauritiana* Lam.) 及草莓 (*Fragaria* × *ananassa* Duchesne) 等作物或因栽培面積較少, 或因炭疽病非該作物的主要病害, 致其登記藥劑少且以延伸使用藥劑為主, 可視為果樹類炭疽病少量使用的代表作物。這兩種類型作物的炭疽病用藥對其標的病原菌在藥效上否有別, 將於本研究中作探討。

藥效評估的目的在運用有效率且可信的方法針對藥劑的有效性進行系統性評估, 以推斷其實際的防治效果, 並希能在實驗室執行以節約成本。炭疽病菌除產生菌絲外, 亦能產生大量分生孢子, 菌絲生長與孢子發芽皆是良好的藥效評估指標⁽⁴⁶⁾。為測試藥劑對孢子發芽的抑制作用, 常以系列稀釋藥劑與孢子混合於載玻片,

經一定作用時間後, 計數孢子發芽率^(11, 16), 亦有將供試藥劑以特定濃度加入水瓊脂平板再塗上孢子以測試之⁽¹⁴⁾, 或有將各藥劑依其推薦濃度製備成稀釋藥液與孢子混合於微量滴定盤 (microtiter plate), 經一段時間後, 塗布於水瓊脂平板上, 測定其抑菌效果⁽⁷⁾。而測試藥劑對菌絲生長的抑制作用則常用藥劑平板法, 即以定量藥劑混入含菌絲生長所需營養之培養基製成含系列稀釋藥劑的平板^(11, 12, 16, 36, 54)。惟因各種藥劑在田間的實際使用濃度範圍甚廣, 實不宜以統一的系列濃度供試。本研究乃以各藥劑在田間實際使用的濃度 (use rate) 為依據, 配製成各種藥劑的單一稀釋液, 以之測定其對供試菌株孢子發芽及菌絲生長的抑制作用。試驗時, 孢子或菌絲均直接浸泡於藥液內並經一段時間作用, 使藥液充分發揮其抑菌效果, 以視各種藥劑對孢子發芽及菌絲生長之影響。本研究即以芒果炭疽病菌為殺菌劑主要使用之標的菌, 而以酪梨、香蕉、無花果、印度棗及草莓等五種果樹類炭疽病菌為殺菌劑少量使用之標的菌, 運用上述方法評估各種果樹類炭疽病防治藥劑對這兩類型炭疽病菌的藥效, 以為藥劑田間應用及延伸使用制度之參考。

材料與方法

一、供試菌株之分離與鑑定

自 2015 年 6 月至 2016 年 11 月, 分

別前往臺灣各地採集芒果、酪梨、香蕉、無花果、印度棗及草莓等果樹類作物之罹炭疽病果實供分離病原菌。罹病果實攜回實驗室後，先以 70% 乙醇 (ethanol) 作表面消毒，再置於 30.0×22.5×8.0 cm 之有蓋壓克力密閉盒中，盒內鋪以無菌水潤濕之紙巾以保持濕度。經 3 至 4 日，待罹病果實病斑部產生分生孢子盤 (acervulus)，再以玻璃針單孢分離法獲得單孢菌株並培養於馬鈴薯葡萄糖洋菜培養基 (potato dextrose agar, PDA)，置於 24°C 及每日光照 12 小時之定溫箱，供後續試驗之用。培養 7 日所得之菌種復以直徑 5 mm 打孔器切取菌落周邊菌絲塊，放入內裝 1 mL 無菌水之 2-mL 冷凍小管 (cryogenic vial, Nalge Co., Rochester, NY, USA)，置 16°C 定溫箱作長期保存。上述六種果樹炭疽病菌經二年之採集，乃選取源自芒果之炭疽病菌 12 株，作為藥劑“主要使用”之供試菌株；又選取源自草莓 4 株及酪梨、香蕉、無花果、印度棗各 2 株計 12 株炭疽病菌作為藥劑“少量使用”之供試菌株 (表一)。為鑑定此 24 株供試菌株之學名 (scientific name)，爰先以各菌株之分生孢子形態區分其複合種，再以 5 種炭疽病菌鑑定用基因之序列進行比對分析，以獲知其所屬菌種 (species)。為進行菌株基因定序，供試菌株分別接種於馬鈴薯葡萄糖洋菜培養基平板，並於 24°C 及每日光照 12 小時之定溫箱培養 7 日。刮取菌絲後，以核酸萃取套組 (AllPure Plant Genomic DNA Kit；百歐生技公司，臺灣) 抽取基

因組核酸 (genomic DNA)。接著以聚合酶連鎖反應 (polymerase chain reaction, PCR) 增幅核糖體核酸內轉錄間隔區 (ITS, 引子對 ITS1 / ITS4)⁽⁵³⁾、甘油醛-3-磷酸脫氫酶 (GAPDH, 引子對 GDF1 / GDR1)⁽³¹⁾、肌動蛋白 (ACT, 引子對 ACT512F / ACT783R)⁽¹⁹⁾、微管蛋白 (TUB2, 引子對 T1 / T2)⁽⁴¹⁾ 及 Apn2-Mat1-2 intergenic spacer (ApMat, 引子對 AM-F / AM-R)^(47, 49) 等 5 種基因序列。聚合酶連鎖反應之引子對黏合溫度 (annealing temperature) 依不同基因而異，分別為 ITS (55°C)、TUB2 (52°C)、GAPDH (55°C)、ACT (55°C) 及 ApMat (60°C)，均作用 30 sec；其他聚合酶連鎖反應相關之材料與方法悉參照著者已發表報告為之⁽⁹⁾。接著以聚合酶連鎖反應產物進行基因雙向定序，定序結果整理成序列重疊群 (sequence contig)⁽⁵⁰⁾ 供後續菌種鑑定之用。供試菌株之鑑定是以上述 5 種基因序列分別與炭疽病菌菌種之模式菌株 (ex-type culture)^(24, 25, 34, 44, 51) 的相同基因序列作比對，以基因序列相同百分率 (percent identity) 表示之，綜合形態特徵及各基因序列比對結果判定各菌株之所屬菌種。

二、供試殺菌劑

依據藥毒所網站之「植物保護資訊系統」⁽⁴⁾，選取芒果炭疽病登記用藥 21 種及其他果樹類作物炭疽病用藥 12 種，合

表一、本研究所用果樹類炭疽病菌列表

Table 1. *Colletotrichum* isolates used in this study

Isolate	Host	Location	Collection date
MC2	Mango	Fangliao, Pingtung	Jun. 2015
MC3	Mango	Wufeng, Taichung	Jun. 2015
MC4	Mango	Fangshan, Pingtung	Jun. 2015
MC6	Mango	Fengshan, Kaohsiung	Jun. 2015
MC9	Mango	Yuching, Tainan	Jul. 2015
MC10	Mango	Zuozhen, Tainan	Jul. 2015
MC14	Mango	Yuching, Tainan	Jul. 2015
MC17	Mango	Nanhua, Tainan	Jul. 2015
MC22	Mango	Fangliao, Pingtung	Dec. 2015
MC23	Mango	Fangliao, Pingtung	May. 2016
MC25	Mango	Nanhua, Tainan	Jul. 2016
MC26	Mango	Yuching, Tainan	Jul. 2016
AC1	Avocado	Danei, Tainan	Jan. 2016
AC2	Avocado	Shueili, Nantou	Sep. 2016
BC1	Banana	Caotun, Nantou	Oct. 2015
BC2	Banana	Meishan, Chiayi	Nov. 2015
FC1	Fig	Lukang, Changhua	Jun. 2015
FC2	Fig	Linnei, Yunlin	Jul. 2015
JC1	Indian jujube	Yanchao, Kaohsiung	Mar. 2015
JC3	Indian jujube	Liouguei, Kaohsiung	Nov. 2016
SBC1	Strawberry	Guoshing, Nantou	Dec. 2015
SBC4	Strawberry	Shanhua, Tainan	Jan. 2016
SBC5	Strawberry	Dahu, Miaoli	Jan. 2016
SBC7	Strawberry	Dahu, Miaoli	Mar. 2016

計 33 種藥劑作為本研究之供試藥劑，均為購自本地農藥零售店之成品農藥或藥毒所檢驗合格之成品農藥殘留樣品（表二）。供試藥劑類別以固醇去甲基化抑制劑類（sterol demethylation inhibitors, DMIs）為主，其次為醌外抑制劑類（quinone outside inhibitors, QoIs）之甲氧基丙烯酸酯類（史托比類，strobilurins），再次為苯

併咪唑類（benzimidazoles）。供試藥劑屬多點作用機制藥劑（multi-site）有 4 類，其餘分屬 11 類單點作用機制藥劑（specific-site）⁽⁴⁾。芒果炭疽病之防治用藥計 21 種，均非延伸使用，可視該病為藥劑主要使用之對象。登記於其他 5 種果樹類炭疽病之藥劑種類較少且多為延伸使用，例如，用於香蕉及無花果炭疽病之藥

表二、本研究所用殺菌劑之種類、劑型、作用機制代碼及使用劑量

Table 2. Fungicides used in this study

Fungicide	Formulation	FRAC code ¹⁾	Use rate ($\mu\text{g a.i./mL}$) ²⁾
Azoxystrobin	23% SC	11	115
Azoxystrobin 20% + difenoconazole 12.5%	32.50% SC	11, 3	108.3
Bordeaux mixture	72% WP	M1	1500
Boscalid 12.8% + pyraclostrobin 25.2%	38% WG	7, 11	253
Carbendazim	41.7% WG	1	209
Carbendazim 24.5% + hexaconazole 10%	34.5% SC	1, 3	115
Carbendazim 8.6% + prochloraz 23%	31.6% SE	1, 3	105
Cyprodinil 37.5% + fludioxonil 25%	62.5% WG	9, 12	313
Difenoconazole	24.9% EC	3	166
Dithianon	42.2 SC	M9	352
Dithianon 12% + pyraclostrobin 4%	16% WG	M9, 11	107
Fluazinam	39.5% SC	29	198
Fosetyl-aluminium	80% WP	33	667
Fosetyl-aluminium 40% + oxine-copper 40%	80% WP	33, M1	667
Iminoctadine triacetate	25% SL	M7	267
Iprodione	23.7% SC	2	296
Kasugamycin hydrochloride hydrate 3% + carbendazim 40%	43% WP	24, 1	430
Kresoxim-methyl	44.2% SC	11	250
Mancozeb	80% WP	M3	550
Manganese prochlorate	50% WP	3	83
Metconazole	9% SL	3	120
Metiram	80% WG	M3	1600
Myclobutanil	40% WP	3	1000
Oxine-copper	40% WP	M1	267
Polyoxins	50% SG	19	167
Polyoxins 5% + oxine-copper 45%	50% WP	19, M1	500
Prochloraz	25% EW	3	100
Propineb	70% WP	M3	1750
Pyraclostrobin	23.6% EC	11	79
Tebuconazole	25.9% EW	3	173
Tetraconazole	11.60% EW	3	77
Thiabendazole	41.8% SC	1	418
Thiabendazole 18%+ oxine-copper 35%	53% WP	1, M1	442

¹⁾ Fungicide Resistance Action Committee (FRAC).²⁾ Use rate represents the active ingredient concentration in a label recommended on crops.

劑均為延伸使用，印度棗及酪梨炭疽病用藥則分別有 80% 及 70% 之用藥為延伸使用，而草莓炭疽病用藥亦有半數來自延伸使用，延伸使用可視為藥劑少量使用之用途範圍，而這 5 種炭疽病則為藥劑少量使用之對象 (表三)。

三、殺菌劑對炭疽病菌分生孢子發芽之影響

本試驗以微量滴定板法⁽⁷⁾ 測試 33 種果樹類炭疽病防治藥劑 (表二) 對 12 株芒果炭疽病菌及 12 株酪梨等 5 種果樹類炭疽病菌 (表一) 分生孢子發芽的抑制作用。供試藥劑之藥液配製是以無菌蒸餾水稀釋至田間施用之推薦濃度 (表三)⁽⁴⁾。測試時，取 49 μL 供試藥液分別滴入微量滴定板之盤穴 (well)，再加入 1 μL 供試菌株之孢子懸浮液 (1×10^5 spores / mL)，均勻混合。另以供試菌加入無菌水之處理為對照。處理後之微量滴定板覆以封口膜 (parafilm, PM-996) 以防水分蒸散並置於實驗室 (24~28°C)。2 小時後，將盤穴內之混合液分別塗布於直徑 9 公分之 2% 洋菜 (water agar) 平板上，洋菜平板靜置於 24°C 黑暗定溫箱。24 小時後，於光學顯微鏡下計數孢子發芽率。每處理 4 重複，每重複計數 200 個孢子，以百分率表示孢子發芽率。各處理之發芽百分率先進行顯著性分析 (One-way analysis of variance, ANOVA)，差異達 5% 顯著水準，則對處理間之差異進行費雪最小顯著差異測驗

(Fisher's protected least significance test, LSD, 5%)。

四、殺菌劑對炭疽病菌菌絲生長之影響

為測試各種殺菌劑 (表二) 對各種果樹炭疽病菌 (表一) 菌絲生長之影響，乃以各菌株培養於馬鈴薯葡萄糖洋菜培養基 7 日之菌落為接種源，並以直徑 5 mm 打孔器切取菌落周緣之菌絲塊，將之放入注有 100 μL 供試藥液之微量滴定板盤穴內並置室溫下。另以菌絲塊加入無菌水之處理為對照。供試藥劑之稀釋方法及濃度同於前項試驗。處理 2 小時後，以移植針將菌絲塊挑出，置滅菌過之吸水紙將藥液吸乾，並移置於直徑 9 cm 之馬鈴薯葡萄糖洋菜培養基平板中央，於 24°C 無光照之定溫箱培養 5 日。以通過菌落中心點之兩條垂直線為準，量取菌落直徑，並以二者之平均值為該菌落之直徑度量，以比較藥劑之抑菌效果。每菌株每藥劑處理 4 重複。

結果

一、炭疽病菌之鑑定

供試炭疽病菌在馬鈴薯葡萄糖洋菜培養基經 7 日之培養，以菌落產生之分生孢子作形態鑑別。僅有一芒果菌株 MC14 之分生孢子一端尖形 (acute)、一端圓形 (round) 屬 *C. acutatum* 複合種，其他 23 株

表三、供試藥劑對六種果樹類炭疽病之登記使用現況

Table 3. Label, off-label and extension use of fungicides for controlling anthracnose diseases of various fruit crops¹⁾

Fungicide	Mango	Avocado	Banana	Fig	Indian jujube	Strawberry
Azoxystrobin	+	+	±	±	+	-
Azoxystrobin + difenoconazole	+	±	±	-	-	-
Bordeaux mixture	-	-	-	-	-	-
Boscalid + pyraclostrobin	-	-	-	-	-	-
Carbendazim	-	-	-	-	-	-
Carbendazim + hexaconazole	+	-	-	-	-	-
Carbendazim + prochloraz	+	-	-	-	-	-
Cyprodinil + fludioxonil	+	+	±	±	-	-
Difenoconazole	+	-	±	-	-	+
Dithianon	+	-	-	±	-	-
Dithianon + pyraclostrobin	+	-	-	±	-	-
Fluazinam	+	-	-	±	-	-
Fosetyl-aluminium	-	-	-	-	-	-
Fosetyl-aluminium + oxine-copper	-	-	-	-	-	-
Iminoctadine triacetate	+	±	±	±	-	-
Iprodione	+	-	-	±	-	-
Kasugamycin + carbendazim	+	-	-	-	-	-
Kresoxim-methyl	+	-	-	±	±	-
Mancozeb	+	-	-	±	-	-
Manganese prochlorate	+	-	-	-	-	-
Metconazole	+	-	-	-	-	-
Metiram	+	±	±	±	±	-
Myclobutanil	-	-	-	-	-	-
Oxine-copper	-	-	-	-	-	-
Polyoxins	-	-	-	-	-	-
Polyoxins + oxine-copper	-	-	-	-	-	-
Prochloraz	-	-	-	-	-	-
Propineb	+	-	-	-	-	-
Pyraclostrobin	+	±	±	±	±	±
Tebuconazole	+	±	±	±	-	-
Tetraconazole	-	-	-	-	-	-
Thiabendazole	-	+	-	-	-	-
Thiabendazole + oxine-copper	+	-	-	±	-	+

¹⁾ +, registered (non-extension use); ±, registered (extension use); -, non-registered.

菌株之分生孢子均為兩端圓形屬 *C. gloeosporioides* 複合種。供試菌株以其 5 種基因序列 (ITS、GAPDH、ACT、TUB2、ApMat) 進行比對分析，結果得知，芒果炭疽病菌以 *C. asianum* 為主要菌種，計有 9 株，另有 2 株 *C. siamense* 及 1 株 *C. scovillei*。而其他果樹類炭疽病菌則乏優勢菌種，菌種較多元，計有 *C. fruticola* 3 株、*C. musae* 1 株、*C. siamense* 5 株、*C. theobromicola* 1 株及 *C. tropicale* 2 株 (表四)。

二、殺菌劑對炭疽病菌孢子發芽之影響

供試 33 種藥劑對芒果炭疽病菌及其他果樹類炭疽病菌等二組菌株之分生孢子發芽的抑制作用是一致的，亦即凡一種藥劑能抑制芒果炭疽病菌孢子發芽亦能抑制其他果樹類炭疽病菌，反之，如一種藥劑對芒果炭疽病菌孢子無藥效，則其對其他果樹類炭疽病菌亦無藥效，即藥劑之藥效具普遍性。此外，凡無抑制作用之藥劑處理，各菌株之孢子發芽率多達 100%；而有效藥劑之處理，則各菌株之孢子發芽率多為 0%。凡孢子未發芽之處理均連續觀察一周，部分孢子且經臺盼藍水溶液 (0.2% trypan blue) 染色，確定孢子已死亡。在兩組炭疽病菌的試驗中，腓硫醯 (dithianon)、腓硫克敏 (dithianon + pyraclostrobin)、扶吉胺 (fluazinam)、福賽快得寧 (fosetyl-aluminium + oxine-

copper)、快得寧 (oxine-copper)、保粒黴素 (甲) (polyoxins)、保粒快得寧 (polyoxines + oxine-copper) 及腐絕快得寧 (thiabendazole + oxine-copper) 等 8 種藥劑可完全抑制芒果及其他果樹類炭疽病菌之孢子發芽。克熱淨 (Iminoctadine triacetate)、鋅錳乃浦 (mancozeb)、免得爛 (metiram) 及甲基鋅乃浦 (propineb) 等 4 種藥劑可抑制全部或絕大部分之芒果及其他果樹類炭疽病菌之孢子發芽。但免得爛及甲基鋅乃浦對芒果菌株 MC2 孢子則無抑制作用，是少見的抗藥菌株。無花果菌株 (FC1, FC2) 亦能對甲基鋅乃浦表現輕微抗藥性及對鋅錳乃浦表現強抗藥性，又無花果菌株 FC1 對克熱淨有輕微抗藥性，酪梨菌株 AC1 對鋅錳乃浦表現輕微抗藥性，而印度棗菌株 JC1 對克熱淨表現中等抗藥性。

其他藥劑如亞托敏 (azoxystrobin)、亞托待克利 (azoxystrobin + difenoconazole)、波爾多 (Bordeaux mixture)、白列克敏 (boscalid + pyraclostrobin)、貝芬替 (carbendazin)、貝芬菲克利 (carbendazin + hexaconazole)、貝芬撲克拉 (carbendazin + prochloraz)、賽普護汰寧 (cyprodinil + fludioxonil)、待克利 (difenoconazole)、福賽得 (fosetyl-aluminium)、依普同 (iprodione)、嘉賜貝芬 (kasugamycin + carbendazin)、克收欣 (kresoxim-methyl)、撲克拉錳 (manganese prochlorate)、滅特座 (metconazole)、邁克尼 (myclobutanil)、撲克拉 (prochloraz)、百克敏 (pyraclostrobin)、

表四、本研究所用果樹類炭疽病菌之分子鑑定

Table 4. Molecular identification of *Colletotrichum* isolates based on their identity to given gene sequences

Isolate ²⁾	Host	Species	Reference culture ³⁾	Percent identity (%) ¹⁾					ApMat ⁴⁾
				ITS	GAPDH	ACT	TUB2		
MC2	Mango	<i>C. siamense</i>	MFLU 090230	100 / FJ972613	99 / FJ972575	99 / FJ907423	98 / FJ907438	99 / JQ899289	
MC3	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	95 / FJ972576	100 / FJ907424	100 / FJ907439	99 / FR718814	
MC4	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	95 / FJ972576	100 / FJ907424	100 / FJ907439	99 / FR718814	
MC6	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	95 / FJ972576	100 / FJ907424	99 / FJ907439	99 / FR718814	
MC9	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	94 / FJ972576	100 / FJ907424	99 / FJ907439	99 / FR718814	
MC10	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	94 / FJ972576	100 / FJ907424	100 / FJ907439	99 / FR718814	
MC14	Mango	<i>C. scovillei</i>	CBS 126529	100 / JQ948267	97 / JQ948597	99 / JQ949588	100 / JQ949918	NA	
MC17	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	94 / FJ972576	100 / FJ907424	99 / FJ907439	99 / FR718814	
MC22	Mango	<i>C. siamense</i>	MFLU 090230	100 / FJ972613	99 / FJ972575	99 / FJ907423	98 / FJ907438	99 / JQ899289	
MC23	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	95 / FJ972576	100 / FJ907424	99 / FJ907439	99 / FR718814	
MC25	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	94 / FJ972576	100 / FJ907424	100 / FJ907439	99 / FR718814	
MC26	Mango	<i>C. asianum</i>	MFLU 090233	99 / FJ972612	94 / FJ972576	100 / FJ907424	99 / FJ907439	99 / FR718814	
AC1	Avocado	<i>C. theobromicola</i>	CBS 124945	99 / JX010294	99 / JX 010006	99 / JX009444	99 / JX010447	97 / KC790726	
AC2	Avocado	<i>C. fructicola</i>	MFLU 090228	99 / FJ972603	99 / FJ972578	99 / FJ907426	100 / FJ907441	99 / JQ807838	
BC1	Banana	<i>C. musae</i>	CBS 116870	99 / JX010146	100 / JX010050	99 / JX009433	97 / HQ596280	NA	
BC2	Banana	<i>C. siamense</i>	MFLU 090230	99 / FJ972613	96 / FJ972575	99 / FJ907423	99 / FJ907438	99 / JQ899289	
FC1	Fig	<i>C. tropicale</i>	CBS 124949	99 / JX010264	98 / JX010007	99 / JX009489	99 / JX010407	100 / KC790728	
FC2	Fig	<i>C. tropicale</i>	CBS 124949	99 / JX010264	98 / JX010007	99 / JX009489	100 / JX010407	100 / KC790728	
JC1	In. Jujube	<i>C. fructicola</i>	MFLU 090228	100 / FJ972603	100 / FJ972578	99 / FJ907426	100 / FJ907441	99 / JQ807838	
JC3	In. Jujube	<i>C. siamense</i>	MFLU 090230	99 / FJ972613	99 / FJ972575	99 / FJ907423	98 / FJ907438	99 / JQ899289	
SBC1	Strawberry	<i>C. siamense</i>	MFLU 090230	99 / FJ972613	99 / FJ972575	99 / FJ907423	99 / FJ907438	99 / JQ899289	
SBC4	Strawberry	<i>C. siamense</i>	MFLU 090230	99 / FJ972613	99 / FJ972575	99 / FJ907423	99 / FJ907438	98 / JQ899289	
SBC5	Strawberry	<i>C. fructicola</i>	MFLU 090228	100 / FJ972603	99 / FJ972578	99 / FJ907426	100 / FJ907441	NA	
SBC7	Strawberry	<i>C. siamense</i>	MFLU 090230	99 / FJ972613	99 / FJ972575	99 / FJ907423	98 / FJ907438	98 / JQ899289	

¹⁾ Percent identity: identity between each gene sequence of the isolate with that of the reference culture in percentage ratio / Genbank accession number of the gene sequence of reference culture; ITS: complete rDNA -ITS region; GAPDH: glyceraldehyde-3-phosphate dehydrogenase; ACT: actin; TUB2: partial β -tubulin; ApMat: Apn2-Mat1-2 intergenic spacer.

²⁾ Refer to table 1 for isolate information.

³⁾ Reference culture: ex-type or authentic culture of each *Colletotrichum* species.

⁴⁾ Not available.

得克利 (tebuconazole)、四克利 (tetraconazole) 及腐絕 (thiabendazole) 等 21 種殺菌劑則分別對全部或絕大部份供試菌株之孢子發芽無抑制作用 (表五、六)。

三、殺菌劑對炭疽病菌菌絲生長之影響

供試 33 種藥劑對芒果炭疽病菌及其他果樹類炭疽病菌之菌絲生長的抑制作用也是一致的，亦即凡一種藥劑能抑制芒果炭疽病菌菌絲生長亦能抑制其他果樹類炭疽病菌之菌絲生長，反之，亦然。大部分供試藥劑對兩類炭疽病菌之菌絲生長均無抑制作用，惟供試藥劑中含撲克拉成分者如撲克拉、撲克拉錳及貝芬撲克拉則有顯著藥效，對芒果炭疽病菌之藥效尤佳。撲克拉可抑制供試之 12 株芒果炭疽病菌及其他果樹類炭疽病菌之大部分菌株的菌絲生長，撲克拉錳及貝芬撲克拉的藥效與撲克拉類似。滅特座可抑制半數芒果菌株之生長，但僅能抑制 1 株香蕉菌株 (BC1) 之生長。福賽快得寧可抑制約半數之芒果及其他果樹類菌株之生長，但單劑福賽得及快得寧則均無抑制菌絲生長作用。此外，貝芬菲克利、賽普護汰寧、克熱淨及嘉賜貝芬等藥劑對兩類炭疽病菌之少數菌株 (1~4 株) 具抑制生長之作用，而待克利對 1 株芒果菌株 (MC4) 及邁克尼對 1 株香蕉菌株 (BC1) 具抑制生長之作用 (表七、八)。

討論

病原菌是植物傳染性病害的致病因子，也是病害防治的標的，其菌種之分類鑑定是研究病害首要釐清的問題。以往臺灣甚少對炭疽病菌作分子鑑定，而多以有限的形態特徵或其寄主植物學名來命名。但一種果樹可能受數種 (species) 炭疽病菌感染，而單一種炭疽病菌亦可感染不同種類的果樹^(17, 28, 29)，因此，炭疽病菌亦不宜依其寄主植物學名來命名。由於形態特徵少且變異不大，因而炭疽病菌僅見少數幾個菌種，許多作物炭疽病菌即是以 *C. gloeosporioides* 命名⁽¹⁾，但這個學名是有待商榷的⁽⁴³⁾，現代分子生物學的應用已徹底改變此類真菌的分類與命名^(33, 34)。本研究所用各種果樹類炭疽病菌經分生孢子形態鑑定，以 *C. gloeosporioides* 複合種居絕對多數，供試之 24 株果樹炭疽病菌即有 23 株屬之，僅一菌株 MC14 為 *C. acutatum* 複合種，與國內外之調查結果相似^(10, 18, 22)。本研究進一步得知，芒果炭疽病菌是以 *C. asianum* 為優勢種，也類同於國內外相關之報告^(5, 38, 43)。其他五種果樹類之菌種則因菌株數較少，不同果樹各自擁有不同菌種但亦有相同者，且許多菌種為國內首次報告。兩株酪梨炭疽病菌經鑑定分別為 *C. fructicola* 及 *C. theobromicola*，也曾見於以色列之酪梨⁽⁴⁸⁾。香蕉炭疽病菌雖以 *C. musae* 最為常見^(35, 51)，但亦有 *C. siamense*⁽³⁴⁾，後者為國內香蕉炭疽病菌首例。無花果炭疽病菌

表五、殺菌劑對芒果炭疽病菌孢子發芽之影響

Table 5. Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from mango

Fungicide	Germination rate (%) ^{1,2)}		
	MC2	MC3	MC4
Azoxystrobin	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Azoxystrobin + difenoconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Bordeaux mixture	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Boscalid + pyraclostrobin	100.0±0.0 a	23.8±1.3 f	100.0±0.0 a
Carbendazim	100.0±0.0 a	79.8±0.6 d	100.0±0.0 a
Carbendazim + hexaconazole	100.0±0.0 a	90.5±0.5 c	100.0±0.0 a
Carbendazim + prochloraz	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Cyprodinil + fludioxonil	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Difenoconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Dithianon	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Dithianon + pyraclostrobin	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Fluazinam	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Fosetyl-aluminium	100.0±0.0 a	100.0±0.0 a	91.0±0.4 b
Fosetyl-aluminium + oxine-copper	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Iminoctadine triacetate	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Iprodione	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Kasugamycin + carbendazim	100.0±0.0 a	0.0±0.0 h	100.0±0.0 a
Kresoxim-methyl	97.5±0.5 b	100.0±0.0 a	100.0±0.0 a
Mancozeb	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Manganese prochlorate	64.0±1.4 d	52.8±2.3 e	83.0±1.8 c
Metconazole	92.0±0.8 c	0.0±0.0 h	83.3±1.4 c
Metiram	100.0±0.0 a	0.0±0.0 h	0.0±0.0 d
Myclobutanil	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Oxine-copper	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Polyoxins	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Polyoxins + oxine-copper	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Prochloraz	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Propineb	100.0±0.0 a	0.0±0.0 h	0.0±0.0 d
Pyraclostrobin	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Tebuconazole	100.0±0.0 a	92.8±1.1 b	100.0±0.0 a
Tetraconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Thiabendazole	100.0±0.0 a	19.8±0.6 g	91.5±1.0 b
Thiabendazole + oxine-copper	0.0±0.0 e	0.0±0.0 h	0.0±0.0 d
Control (water)	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a

表五 (續)、殺菌劑對芒果炭疽病菌孢子發芽之影響

Table 5 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from mango

Fungicide	Germination rate (%) ^{1,2)}		
	MC6	MC9	MC10
Azoxystrobin	40.5±0.5 k	82.0±1.1 e	63.0±1.3 g
Azoxystrobin + difenoconazole	46.5±0.6 j	100.0±0.0 a	96.3±0.9 b
Bordeaux mixture	45.5±1.3 j	100.0±0.0 a	100.0±0.0 a
Boscalid + pyraclostrobin	0.0±0.0 p	100.0±0.0 a	0.0±0.0 o
Carbendazim	90.0±0.4 a	92.3±1.1 c	21.5±0.6 l
Carbendazim + hexaconazole	70.3±0.9 g	90.8±0.5 c	43.5±1.6 j
Carbendazim + prochloraz	73.8±1.1 ef	100.0±0.0 a	49.8±2.2 i
Cyprodinil + fludioxonil	91.5±1.0 a	51.5±1.7 f	94.5±1.7 bc
Difenoconazole	32.5±1.0 l	100.0±0.0 a	85.5±2.5 e
Dithianon	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Dithianon + pyraclostrobin	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Fluazinam	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Fosetyl-aluminium	86.5±2.5 b	95.3±0.9 b	92.8±1.4 cd
Fosetyl-aluminium + oxine-copper	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Iminoctadine triacetate	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Iprodione	80.8±0.5 c	100.0±0.0 a	90.3±0.5 d
Kasugamycin + carbendazim	78.5±1.2 cd	52.5±1.6 f	67.0±1.5 f
Kresoxim-methyl	71.8±1.0 fg	90.0±0.4 c	0.0±0.0 o
Mancozeb	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Manganese prochlorate	5.7±1.1 o	39.3±1.9 g	91.0±1.3 d
Metconazole	72.8±1.1 fg	0.0±0.0 h	19.8±0.6 l
Metiram	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Myclobutanil	39.5±0.9 k	85.8±0.9 d	19.8±0.9 l
Oxine-copper	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Polyoxins	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Polyoxins + oxine-copper	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Prochloraz	81.0±0.4 c	100.0±0.0 a	91.5±1.0 cd
Propineb	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Pyraclostrobin	16.8±0.5 n	100.0±0.0 a	0.0±0.0 o
Tebuconazole	76.5±0.6 de	82.5±1.2 e	10.8±0.5 m
Tetraconazole	62.5±1.2 h	100.0±0.0 a	53.3±1.8 h
Thiabendazole	53.3±1.3 i	100.0±0.0 a	39.0±1.4 k
Thiabendazole + oxine-copper	0.0±0.0 p	0.0±0.0 h	0.0±0.0 o
Control (water)	80.5±0.6 c	100.0±0.0 a	100.0±0.0 a

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Table 5 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from mango

Fungicide	Germination rate (%) ^{1,2)}		
	MC14	MC17	MC22
Azoxystrobin	100.0±0.0 a	63.0±1.3 g	71.5±1.0 g
Azoxystrobin + difenoconazole	100.0±0.0 a	62.0±0.8 g	90.8±0.5 bc
Bordeaux mixture	100.0±0.0 a	92.3±1.3 b	100.0±0.0 a
Boscalid + pyraclostrobin	0.0±0.0 c	49.8±0.6 j	86.5±1.6 d
Carbendazim	100.0±0.0 a	89.8±0.6 bc	91.5±0.9 bc
Carbendazim + hexaconazole	100.0±0.0 a	87.0±1.1 c	91.8±0.9 bc
Carbendazim + prochloraz	100.0±0.0 a	100.0±0.0 a	92.8±1.1 b
Cyprodinil + fludioxonil	100.0±0.0 a	100.0±0.0 l	89.8±0.6 c
Difenoconazole	100.0±0.0 a	45.0±1.9 k	81.8±0.9 e
Dithianon	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Dithianon + pyraclostrobin	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Fluazinam	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Fosetyl-aluminium	100.0±0.0 a	100.0±0.0 a	76.8±1.4 f
Fosetyl-aluminium + oxine-copper	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Iminoctadine triacetate	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Iprodione	100.0±0.0 a	91.5±1.0 b	71.5±1.0 g
Kasugamycin + carbendazim	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Kresoxim-methyl	100.0±0.0 a	51.5±0.6 j	89.8±0.6 c
Mancozeb	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Manganese prochlorate	92.0±0.91 b	77.8±1.9 e	72.3±2.0 g
Metconazole	92.8±1.1 b	92.3±0.9 b	23.0±1.3 h
Metiram	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Myclobutanil	100.0±0.0 a	81.8±0.9 d	90.8±0.5 bc
Oxine-copper	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Polyoxins	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Polyoxins + oxine-copper	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Prochloraz	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Propineb	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Pyraclostrobin	100.0±0.0 a	62.0±1.1 g	81.0±0.7 e
Tebuconazole	100.0±0.0 a	72.8±1.1 f	100.0±0.0 a
Tetraconazole	100.0±0.0 a	58.8±0.8 h	90.5±0.5 bc
Thiabendazole	100.0±0.0 a	55.0±2.1 i	92.5±1.2 b
Thiabendazole + oxine-copper	0.0±0.0 c	0.0±0.0 l	0.0±0.0 i
Control (water)	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a

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Table 5 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from mango

Fungicide	Germination rate (%) ^{1,2)}		
	MC23	MC25	MC26
Azoxystrobin	100.0±0.0 a	56.3±2.4 h	100.0±0.0 a
Azoxystrobin + difenoconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Bordeaux mixture	94.5±1.8 b	92.0±1.1 bc	97.8±0.6 b
Boscalid + pyraclostrobin	100.0±0.0 a	81.3±0.5 d	100.0±0.0 a
Carbendazim	94.5±1.7 b	62.0±0.9 g	100.0±0.0 a
Carbendazim + hexaconazole	100.0±0.0 a	93.8±0.9 b	100.0±0.0 a
Carbendazim + prochloraz	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Cyprodinil + fludioxonil	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Difenoconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Dithianon	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Dithianon + pyraclostrobin	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Fluazinam	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Fosetyl-aluminium	96.0±0.9 b	100.0±0.0 a	100.0±0.0 a
Fosetyl-aluminium + oxine-copper	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Iminoctadine triacetate	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Iprodione	100.0±0.0 a	84.3±1.7 d	100.0±0.0 a
Kasugamycin + carbendazim	100.0±0.0 a	90.8±0.5 c	100.0±0.0 a
Kresoxim-methyl	100.0±0.0 a	24.8±0.9 j	100.0±0.0 a
Mancozeb	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Manganese prochlorate	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Metconazole	20.0±0.4 e	12.8±1.1 l	7.8±0.6 d
Metiram	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Myclobutanil	100.0±0.0 a	30.3±2.5 i	100.0±0.0 a
Oxine-copper	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Polyoxins	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Polyoxins + oxine-copper	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Prochloraz	96.3±1.0 b	76.3±0.9 e	82.5±0.3 c
Propineb	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Pyraclostrobin	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Tebuconazole	100.0±0.0 a	92.8±1.1 bc	100.0±0.0 a
Tetraconazole	100.0±0.0 a	70.3±0.9 f	100.0±0.0 a
Thiabendazole	89.8±0.6 c	21.3±1.1 k	100.0±0.0 a
Thiabendazole + oxine-copper	0.0±0.0 f	0.0±0.0 m	0.0±0.0 e
Control (water)	100.0±0.0 a	94.8±1.8 b	100.0±0.0 a

¹⁾ Mean±standard error (n=4). Mean values within a column followed by the same letters were not significantly different at 5% level by Fisher's protected least significant difference test. Percentage data were arcsine-square-root transformed prior to analysis.

²⁾ Refer to Table 1 for isolate information.

表六、殺菌劑對其他果樹類炭疽病菌孢子發芽之影響

Table 6. Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from fruit crops other than mango

Fungicide	Germination rate (%) ^{1,2)}		
	AC1	AC2	BC1
Azoxystrobin	100.0±0.0 a	100.0±0.0 a	89.0±0.9 def
Azoxystrobin + difenoconazole	96.5±1.0 b	100.0±0.0 a	84.5±0.6 gh
Bordeaux mixture	85.5±0.6 f	100.0±0.0 a	90.3±0.5 de
Boscalid + pyraclostrobin	5.0±0.4 k	100.0±0.0 a	11.3±0.5 m
Carbendazim	90.8±0.5 de	100.0±0.0 a	64.8±2.9 k
Carbendazim + hexaconazole	91.8±0.9 cde	100.0±0.0 a	77.0±2.4 i
Carbendazim + Prochloraz	85.8±0.9 f	80.5±0.5 e	97.0±0.4 ab
Cyprodinil + fludioxonil	93.5±1.2 bcd	96.8±0.5 c	70.0±1.1 j
Difenoconazole	92.8±1.4 cd	80.8±0.5 e	95.8±0.9 b
Dithianon	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Dithianon + pyraclostrobin	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Fluazinam	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Fosetyl-aluminium	93.8±1.2 bcd	100.0±0.0 a	94.3±0.9 bc
Fosetyl-aluminium + oxine-copper	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Iminoctadine triacetate	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Iprodione	94.8±1.9 bc	100.0±0.0 a	100.0±0.0 a
Kasugamycin + carbendazim	93.6±1.3 bcd	100.0±0.0 a	81.0±1.5 h
Kresoxim-methyl	100.0±0.0 a	100.0±0.0 a	94.0±0.9 bc
Mancozeb	4.5±0.3 k	0.0±0.0 h	0.0±0.0 n
Manganese prochlorate	78.8±2.7 gh	4.8±0.3 g	97.3±0.5 bc
Metconazole	5.5±0.3 k	90.5±0.5 d	24.5±2.3 l
Metiram	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Myclobutanil	19.8±0.5 j	100.0±0.0 a	87.5±1.9 efg
Oxine-copper	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Polyoxins	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Polyoxins + oxine-copper	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Prochloraz	94.0±1.1 bcd	49.0±1.3 f	100.0±0.0 a
Propineb	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Pyraclostrobin	25.5±0.6 i	100.0±0.0 a	74.8±0.5 i
Tebuconazole	80.5±1.8 g	100.0±0.0 a	94.3±1.3 bc
Tetraconazole	96.8±0.9 ab	100.0±0.0 a	96.8±0.5 ab
Thiabendazole	89.3±0.9 e	97.8±0.6 bc	81.3±1.1 h
Thiabendazole + oxine-copper	0.0±0.0 l	0.0±0.0 h	0.0±0.0 n
Control (water)	75.5±0.0 h	98.3±0.9 b	86.3±1.3 fg

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Table 6 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from fruit crops other than mango

Fungicide	Germination rate (%) ^{1,2)}		
	BC2	FC1	FC2
Azoxystrobin	97.0±0.9 ab	90.8±0.5 bc	89.8±1.3 fg
Azoxystrobin + difenoconazole	96.0±0.8 ab	47.5±2.8 kl	97.8±0.6 ab
Bordeaux mixture	94.3±0.9 bcd	58.5±2.8 i	75.5±1.6 k
Boscalid + pyraclostrobin	23.0±1.1 i	13.0±1.1 o	10.8±0.5 n
Carbendazim	89.3±2.6 ef	84.5±1.3 de	92.3±1.4 cdef
Carbendazim + hexaconazole	85.8±2.3 fg	84.4±1.2 de	90.5±1.7 ef
Carbendazim + prochloraz	95.8±0.9 bc	42.0±2.4 m	85.8±1.2 gh
Cyprodinil + fludioxonil	94.8±1.1 bcd	94.0±1.1 b	96.0±0.8 abc
Difenoconazole	95.8±0.5 bc	78.0±1.1 fg	95.0±0.6 bcd
Dithianon	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Dithianon + pyraclostrobin	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Fluazinam	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Fosetyl-aluminium	96.3±0.9 ab	66.3±1.3 h	94.8±0.5 bcde
Fosetyl-aluminium + oxine-copper	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Iminoctadine triacetate	0.0±0.0 j	5.5±0.6 p	0.0±0.0 o
Iprodione	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Kasugamycin + carbendazim	90.8±0.5 de	85.3±0.9 de	89.8±0.6 fg
Kresoxim-methyl	95.0±1.5 bc	44.5±1.2 lm	80.3±2.5 ij
Mancozeb	0.0±0.0 j	86.3±1.1 cde	90.8±0.5 def
Manganese prochlorate	96.8±0.5 ab	73.8±0.9 g	85.8±2.1 gh
Metconazole	23.0±1.6 i	13.0±1.1 o	39.5±3.8 l
Metiram	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Myclobutanil	63.3±2.6 h	52.3±3.0 jk	82.3±0.9 hij
Oxine-copper	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Polyoxins	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Polyoxins + oxine-copper	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Prochloraz	100.0±0.0 a	89.0±2.0 bcd	88.8±1.6 fg
Propineb	0.0±0.0 j	16.5±0.6 o	16.3±0.9 m
Pyraclostrobin	93.3±1.3 bcde	27.8±2.2 n	83.5±1.3 hi
Tebuconazole	91.8±1.7 cde	56.3±2.0 ij	89.3±0.9 fg
Tetraconazole	100.0±0.0 a	31.5±3.0 n	88.3±1.9 fg
Thiabendazole	84.8±1.8 g	82.0±0.9 ef	94.3±0.9 bcde
Thiabendazole + oxine-copper	0.0±0.0 j	0.0±0.0 q	0.0±0.0 o
Control (water)	100.0±0.0 a	78.8±1.1 fg	78.7±1.0 jk

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Table 6 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from fruit crops other than mango

Fungicide	Germination rate (%) ^{1,2)}		
	JC1	JC3	SBC1
Azoxystrobin	96.5±0.6 abc	6.3±0.6 n	16.8±0.9 i
Azoxystrobin + difenoconazole	96.3±0.9 abc	50.3±0.6 i	90.8±0.5 bc
Bordeaux mixture	41.3±2.7 k	94.8±1.7 b	100.0±0.0 a
Boscalid + pyraclostrobin	0.0±0.0 o	10.0±0.8 m	86.5±1.6 d
Carbendazim	36.3±0.9 m	68.3±0.6 f	91.5±0.9 bc
Carbendazim + hexaconazole	92.5±1.8 cd	83.8±1.3 d	91.8±0.9 bc
Carbendazim + prochloraz	96.3±0.9 abc	74.5±1.2 e	92.8±1.1 b
Cyprodinil + fludioxonil	88.0±2.3 ef	48.2±0.9 i	89.8±0.6 c
Difenoconazole	96.8±0.5 ab	61.5±1.0 g	81.8±0.9 e
Dithianon	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Dithianon + pyraclostrobin	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Fluazinam	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Fosetyl-aluminium	97.3±0.5 ab	62.3±0.9 g	76.8±1.4 f
Fosetyl-aluminium + oxine-copper	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Iminoctadine triacetate	25.5±0.6 n	0.0±0.0 o	0.0±0.0 j
Iprodione	97.3±0.5 ab	41.8±2.3 j	71.5±1.0 g
Kasugamycin + carbendazim	61.8±0.9 i	90.8±0.5 c	100.0±0.0 a
Kresoxim-methyl	80.8±2.1 g	90.5±0.5 c	89.8±0.6 c
Mancozeb	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Manganese prochlorate	100.0±0.0 a	37.3±1.7 k	72.3±2.0 g
Metconazole	3.8±0.5 o	16.3±1.0 f	23.0±1.3 h
Metiram	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Myclobutanil	63.0±1.6 i	95.5±0.6 ab	90.8±0.5 bc
Oxine-copper	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Polyoxins	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Polyoxins + oxine-copper	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Prochloraz	100.0±0.0 a	55.3±1.1 h	100.0±0.0 a
Propineb	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Pyraclostrobin	95.8±0.6 bc	68.5±0.6 f	81.0±0.7 e
Tebuconazole	89.8±1.5 de	60.0±3.6 g	100.0±0.0 a
Tetraconazole	39.3±0.9 lm	80.8±0.5 d	90.5±0.5 bc
Thiabendazole	67.8±1.7 h	31.8±0.9 l	92.5±1.2 b
Thiabendazole + oxine-copper	0.0±0.0 o	0.0±0.0 o	0.0±0.0 j
Control (water)	57.5±1.3 j	100.0±0.0 a	100.0±0.0 a

表六 (續)、殺菌劑對其他果樹類炭疽病菌孢子發芽之影響

Table 6 (continued). Effects of fungicides on conidial germination of *Colletotrichum* isolates collected from fruit crops other than mango

Fungicide	Germination rate (%) ^{1, 2)}		
	SBC4	SBC5	SBC7
Azoxystrobin	100.0±0.0 a	91.8±2.0 de	100.0±0.0 a
Azoxystrobin + difenoconazole	100.0±0.0 a	95.3±0.8 cd	100.0±0.0 a
Bordeaux mixture	94.5±1.8 b	80.5±0.5 h	97.8±0.6 b
Boscalid + pyraclostrobin	100.0±0.0 a	31.8±0.6 j	100.0±0.0 a
Carbendazim	94.5±1.7 b	100.0±0.0 a	100.0±0.0 a
Carbendazim + hexaconazole	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Carbendazim + Propineb	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Cyprodinil + fludioxonil	100.0±0.0 a	92.0±2.0 de	100.0±0.0 a
Difenoconazole	100.0±0.0 a	93.5±1.7 d	100.0±0.0 a
Dithianon	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Dithianon + pyraclostrobin	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Fluazinam	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Fosetyl-aluminium	96.0±0.9 b	95.0±1.0 c	100.0±0.0 a
Fosetyl-aluminium + oxine-copper	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Iminoctadine triacetate	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Iprodione	100.0±0.0 a	86.0±1.1 g	100.0±0.0 a
Kasugamycin + carbendazim	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Kresoxim-methyl	100.0±0.0 a	100.0±0.0 a	100.0±0.0 a
Mancozeb	0.0±0.0 d	0.0±0.0 k	0.0±0.0 e
Manganese prochlorate	100.0±0.0 a	74.5±2.2 i	100.0±0.0 a
Metconazole	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Metiram	0.0±0.0 f	0.0±0.0 k	0.0±0.0 d
Myclobutanil	100.0±0.0 a	91.0±0.6 e	100.0±0.0 a
Oxine-copper	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Polyoxins	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Polyoxins + oxine-copper	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Prochloraz	96.3±1.0 b	100.0±0.0 a	82.5±0.3 c
Propineb	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Pyraclostrobin	100.0±0.0 a	93.0±2.3 e	100.0±0.0 a
Tebuconazole	100.0±0.0 a	96.0±0.8 c	100.0±0.0 a
Tetraconazole	100.0±0.0 a	81.5±1.0 h	100.0±0.0 a
Thiabendazole	89.8±0.6 c	87.8±0.9 f	100.0±0.0 a
Thiabendazole + oxine-copper	0.0±0.0 d	0.0±0.0 k	0.0±0.0 d
Control (water)	100.0±0.0 a	98.5±1.0 b	100.0±0.0 a

¹⁾ Mean±standard error (n=4). Mean values within a column followed by the same letters were not significantly different at 5% level by Fisher's protected least significant difference test. Percentage data were arcsine-square-root transformed prior to analysis.

²⁾ Refer to table 1 for isolate information.

表七、殺菌劑對芒果炭疽病菌菌絲生長之影響

Table 7. Effects of fungicides on mycelial growth of *Colletotrichum* isolates collected from mango

Fungicide	Mycelial growth ^{1,2)}			
	MC2	MC3	MC4	MC6
Azoxystrobin	+++	+++	+++	+++
Azoxystrobin + difenoconazole	+++	++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	+++	+++	+++	+++
Carbendazim	+++	+	+++	+++
Carbendazim + hexaconazole	++	—	+	—
Carbendazim + prochloraz	—	—	—	—
Cyprodinil + fludioxonil	++	+	+	+
Difenoconazole	++	++	—	+
Dithianon	+++	+++	+++	+++
Dithianon + pyraclostrobin	+++	+++	+++	+++
Fluazinam	+	++	++	+
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	+++	—	+++	—
Iminoctadine triacetate	+	—	+	+
Iprodione	+++	+++	+++	+++
Kasugamycin + carbendazim	+++	—	+++	—
Kresoxim-methyl	+++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	—	—	—	—
Metconazole	+	—	—	+
Metiram	+++	+++	+++	+++
Myclobutanil	++	++	++	++
Oxine-copper	++	++	++	++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	+++	+++
Prochloraz	—	—	—	—
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	+++	+++	+++
Tebuconazole	+++	+++	+++	+++
Tetraconazole	+++	+++	+++	+++
Thiabendazole	+++	+	+++	+
Thiabendazole + oxine-copper	+++	++	+++	++
Control (water)	+++	+++	+++	+++

表七 (續)、殺菌劑對芒果炭疽病菌菌絲生長之影響

Table 7 (continued). Effects of fungicides on mycelial growth of *Colletotrichum* isolates collected from mango

Fungicide	Mycelial growth ^{1, 2)}			
	MC9	MC10	MC14	MC17
Azoxystrobin	+++	+++	+++	+++
Azoxystrobin + difenoconazole	++	++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	+++	+++	+++	+++
Carbendazim	+++	+++	+++	+++
Carbendazim + hexaconazole	+	+	++	+
Carbendazim + prochloraz	—	—	+	—
Cyprodinil + fludioxonil	+	+	+	++
Difenoconazole	+	+	+++	+
Dithianon	+++	+++	+++	+++
Dithianon + pyraclostrobin	+++	+++	+++	+++
Fluazinam	++	++	+++	++
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	++	++	+++	++
Iminoctadine triacetate	+	+	+++	+
Iprodione	+++	+++	+++	+++
Kasugamycin + carbendazim	+++	+++	+++	+++
Kresoxim-methyl	+++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	—	—	+	—
Metconazole	—	—	++	+
Metiram	+++	+++	+++	+++
Myclobutanil	++	++	++	++
Oxine-copper	+++	+++	++	++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	++	+++
Prochloraz	—	—	—	—
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	+++	+++	+++
Tebuconazole	++	+++	+++	++
Tetraconazole	+++	+++	+++	+++
Thiabendazole	+++	+++	+++	+++
Thiabendazole + oxine-copper	+++	+++	+++	+++
Control (water)	+++	+++	+++	+++

表七 (續)、殺菌劑對芒果炭疽病菌菌絲生長之影響

Table 7 (continued). Effects of fungicides on mycelial growth of *Colletotrichum* isolates collected from mango

Fungicide	Mycelial growth ^{1, 2)}			
	MC22	MC23	MC25	MC26
Azoxystrobin	+++	+++	+++	+++
Azoxystrobin + difenoconazole	+++	++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	+++	+++	+++	+++
Carbendazim	+++	+++	+++	+++
Carbendazim + hexaconazole	+	+	+	+
Carbendazim + prochloraz	—	—	—	—
Cyprodinil + fludioxonil	+++	—	++	—
Difenoconazole	++	++	+	+
Dithianon	+++	+++	+++	+++
Dithianon + pyraclostrobin	+++	+++	+++	+++
Fluazinam	++	+	+++	++
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	—	—	—	—
Iminoctadine triacetate	+	+	—	+
Iprodione	+++	+++	+++	+++
Kasugamycin + carbendazim	+++	+++	+++	+++
Kresoxim-methyl	+++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	—	—	—	—
Metconazole	++	—	—	+
Metiram	+++	+++	+++	+++
Myclobutanil	++	++	++	+
Oxine-copper	+++	+	++	++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	+++	+++
Prochloraz	—	—	—	—
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	+++	+++	+++
Tebuconazole	+++	++	++	++
Tetraconazole	+++	+++	+++	+++
Thiabendazole	+++	+++	+++	++
Thiabendazole + oxine-copper	+++	+++	+++	+++
Control (water)	+++	+++	+++	+++

¹⁾ Diameter range of colony after 5-day-growth on potato dextrose agar: + + +, more than 4.0 cm; + +, 2.1 to 4.0 cm; +, 0.1 to 2.0 cm; —, no growth.

²⁾ Refer to table 1 for isolate information.

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Table 8. Effects of fungicides on mycelia growth of *Colletotrichum* isolates from fruit crops other than mango

Fungicide	Mycelial growth ^{1,2)}			
	AC1	AC2	BC1	BC2
Azoxystrobin	+++	++	++	++
Azoxystrobin + difenoconazole	++	++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	++	+++	+++	++
Carbendazim	+	+++	+++	++
Carbendazim + hexaconazole	-	++	-	+
Carbendazim + prochloraz	-	-	-	-
Cyprodinil + fludioxonil	++	-	+	++
Difenoconazole	+	+	+	+
Dithianon	+++	++	+++	+++
Dithianon + pyraclostrobin	+++	+++	++	++
Fluazinam	+	+	++	++
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	+++	-	-	+
Iminoctadine triacetate	+	-	-	++
Iprodione	+++	++	++	+++
Kasugamycin + carbendazim	-	+++	+	+
Kresoxim-methyl	+++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	+	-	-	-
Metconazole	+	++	-	++
Metiram	+++	+++	+++	+++
Myclobutanil	++	++	-	++
Oxine-copper	+++	++	++	+++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	+++	+++
Prochloraz	-	-	-	-
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	++	++	++
Tebuconazole	++	+	+	++
Tetraconazole	+++	+++	++	+++
Thiabendazole	+	++	+++	+
Thiabendazole + oxine-copper	+	+++	+++	++
Control (water)	+++	+++	+++	+++

表八 (續)、殺菌劑對其他果樹類炭疽病菌菌絲生長之影響

Table 8 (continued). Effects of fungicides on mycelia growth of *Colletotrichum* isolates from fruit crops other than mango

Fungicide	Mycelial growth ^{1,2)}			
	FC1	FC2	JC1	JC3
Azoxystrobin	++	+++	+++	+++
Azoxystrobin + difenoconazole	++	++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	+++	+++	+++	+++
Carbendazim	++	+	+	+
Carbendazim + hexaconazole	+	+	+	+
Carbendazim + prochloraz	—	—	—	—
Cyprodinil + fludioxonil	++	++	++	+++
Difenoconazole	+	+	+	+
Dithianon	+++	+++	+++	+++
Dithianon + pyraclostrobin	+++	+++	+++	+++
Fluazinam	+	++	+	+
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	++	++	—	—
Iminoctadine triacetate	+++	+++	—	—
Iprodione	+++	+++	+++	+++
Kasugamycin + carbendazim	+	+	+	—
Kresoxim-methyl	++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	—	—	—	—
Metconazole	++	++	++	++
Metiram	+++	+++	+++	+++
Myclobutanil	++	+	++	++
Oxine-copper	+++	+++	+++	+++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	+++	+++
Prochloraz	—	—	—	—
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	+++	+++	+++
Tebuconazole	+++	+++	++	++
Tetraconazole	+++	+++	+++	+++
Thiabendazole	+	+	+	+
Thiabendazole + oxine-copper	+	++	+	+
Control (water)	+++	+++	+++	+++

表八 (續)、殺菌劑對其他果樹類炭疽病菌菌絲生長之影響

Table 8 (continued). Effects of fungicides on mycelia growth of *Colletotrichum* isolates from fruit crops other than mango

Fungicide	Mycelial growth ^{1,2)}			
	SBC1	SBC4	SBC5	SBC7
Azoxystrobin	+++	+++	+++	+++
Azoxystrobin + difenoconazole	++	+++	++	++
Bordeaux mixture	+++	+++	+++	+++
Boscalid + pyraclostrobin	+++	+++	++	+++
Carbendazim	+++	+++	+++	+++
Carbendazim + hexaconazole	++	+++	++	++
Carbendazim + prochloraz	+	+	—	+
Cyprodinil + fludioxonil	+++	+++	++	++
Difenoconazole	++	+++	+	+++
Dithianon	+++	+++	+++	+++
Dithianon + pyraclostrobin	+++	+++	+++	+++
Fluazinam	+	+	++	+++
Fosetyl-aluminium	+++	+++	+++	+++
Fosetyl-aluminium + oxine-copper	++	+	—	++
Iminoctadine triacetate	+++	+++	+	+++
Iprodione	+++	++	+++	+++
Kasugamycin + carbendazim	+++	+++	+++	+++
Kresoxim-methyl	+++	+++	+++	+++
Mancozeb	+++	+++	+++	+++
Manganese prochlorate	+	+	—	+
Metconazole	++	++	++	+++
Metiram	+++	+++	+++	+++
Myclobutanil	+++	++	++	++
Oxine-copper	+++	+++	+++	+++
Polyoxins	+++	+++	+++	+++
Polyoxins + oxine-copper	+++	+++	+++	+++
Prochloraz	+	+	—	+
Propineb	+++	+++	+++	+++
Pyraclostrobin	+++	+++	+++	+++
Tebuconazole	++	+++	+++	+++
Tetraconazole	+++	+++	+++	+++
Thiabendazole	+++	+++	+++	+++
Thiabendazole + oxine-copper	+++	+++	+++	+++
Control (water)	+++	+++	+++	+++

¹⁾ Diameter range of colony after 5-day-growth on potato dextrose agar: + + +, more than 4.0 cm; +, to 4.0 cm; ++, 0.1 to 2.0 cm; —, no growth.

²⁾ Refer to table 1 for isolate information.

在國內曾有記載為 *C. caricae*⁽¹⁾，係源自其寄主植物學名；本研究所用兩株無花果炭疽病菌經鑑定均為 *C. tropicale*，在國內外均屬首見⁽²⁷⁾。草莓炭疽病菌在國外有記錄之菌種超過 20 種⁽²⁷⁾，國內的記錄種原僅有 *C. gloeosporioides*⁽¹⁾，本研究鑑定其中 3 株為 *C. siamense*，另 1 株為 *C. fructicola* 均為國內草莓新記錄菌種⁽²¹⁾，但為國外常見的草莓炭疽病菌⁽²⁷⁾。今後，臺灣作物炭疽病菌的菌種學名將會因分子生物科技的運用而出現全新面貌。

許多作物炭疽病菌已對多種藥劑產生抗藥性^(15, 32, 52, 54)，本研究亦證實許多炭疽病菌有多重抗藥性 (multiple fungicide resistance) 現象，這些藥劑多屬單點作用機制藥劑。依本研究結果推論，果樹類炭疽病菌對藥劑之抗感性可能與該菌株屬何菌種或源自何寄主植物無涉，亦與該藥劑是否為延伸使用無關。供試藥劑對供試菌株的藥效表現多具一致性，即凡為有效藥劑則多能抑制絕大部分之供試菌株，凡為無效藥劑則對病原菌多無抑制作用，而少有抑制部分菌株之現象。有效抑制炭疽病菌分生孢子發芽與有效抑制其菌絲生長的藥劑種類完全不同，可能因病原菌控制孢子發芽與菌絲生長的分子機制有別^(39, 42)。當進行殺菌劑篩選時，對孢子發芽與菌絲生長的藥效試驗均應為之，才能完整獲知殺菌劑的藥效功能。

有效抑制孢子發芽的藥劑約占供試藥劑的三分之一，且多屬多點作用機制藥劑，如無機銅類 (inorganic copper

compounds) 之快得寧，二硫代胺基甲酸鹽類 (dithiocarbamates) 之鋅錳乃浦、甲基鋅乃浦及免得爛，胍類 (guanidines) 之克熱淨及蔥醌類 (quinines) 之腈硫醌等均屬之。此外，尚有單點作用機制之有效藥劑，如肽醯嘧啶核苷類 (peptidyl pyrimidine nucleosides) 之保粒黴素 (甲) 及二硝基苯胺類 (2,6-dinitroanilines) 之扶吉胺等亦能有效抑制炭疽病菌之孢子發芽。近年來，混合藥劑在國內市場占比漸增，本研究亦測試許多混合劑，發現其藥效表現與所含個別單劑之濃度有關，例如，單劑亞托敏及待克利與混合劑亞托待克利對芒果菌株 MC25 之孢子發芽率的抑制作用即為一例。單劑亞托敏之供試濃度為 115 ppm，此時 MC25 孢子發芽率為 56.3%，單劑待克利供試濃度雖為 166 ppm，卻無抑菌作用 (孢子發芽率 100%)，而混合劑亞托待克利所含亞托敏之濃度為 66.4 ppm，僅及其單劑濃度的 57.7%。混合劑又僅含待克利 41.6 ppm，自無抑菌作用。因此，混合劑亞托待克利處理 MC25，其發芽率必遠高於 56.3%，而趨近 100% (表五)。

能抑制菌絲生長的藥劑種類很少且均為單點作用機制藥劑，僅有咪唑類 (imidazoles) 之撲克拉、撲克拉錳及貝芬撲克拉等 3 藥劑，且均含撲克拉成分，而屬三唑類 (triazoles) 的滅特座則對部分菌株有效。本研究之結果顯示，撲克拉對抑制炭疽病菌菌絲生長表現最優，此與國內外相關研究一致^(18, 20, 36)，但撲克拉在相

同濃度下卻完全不能抑制其孢子發芽，國內亦有類似的研究結果^(12, 16)。謝氏等⁽¹³⁾曾於 1984 年發表關於臺灣中部各葡萄產區晚腐（炭疽）病菌對 4 種推薦藥劑之抗藥性調查報告，當時即指出撲克拉的抗性倍數比 (resistance ratio) 最低，亦即晚腐病菌對撲克拉的抗藥程度最低，其時是以晚腐菌分生孢子發芽率為指標，其半數抑制濃度 (inhibition concentration on 50% conidial germination, IC₅₀) 達 221~410 ppm。本研究在孢子發芽試驗時，撲克拉所用濃度為田間使用之 100 ppm，遠低於謝氏等所用之濃度範圍，推斷如提高撲克拉之使用濃度將可抑制其孢子發芽，但應無必要，因該濃度已足以抑制菌絲生長及附著器形成⁽⁸⁾。另，郭氏⁽³⁶⁾調查臺南地區芒果炭疽病菌對撲克拉之感受性，是以菌絲生長為指標，亦僅見輕微之抗藥性。在本研究中，與撲克拉或滅特座同屬固醇去甲基化抑制劑類 (DMIs) 的其他供試藥劑尚有多種，但其並無抑制炭疽病菌菌絲生長或孢子發芽之作用，相同作用機制的不同藥劑對於誘導病原菌抗藥性族群發展可能存有很大差異。在田間為減緩病原菌抗藥性族群之生成，輪用不同作用機制藥劑與輪用相同作用機制之不同藥劑都應是選項。本研究中曾使用含兩種成分之混合劑，如其一種成分有效，該混合劑即屬有效藥劑。惟福賽快得寧雖可抑制約半數之芒果及半數之其他果樹類炭疽病菌菌株的菌絲生長，但單劑福賽得或快得寧卻並無此作用。由於快得寧是抑制炭疽病菌孢子

發芽的有效藥劑，使用福賽快得寧可兼具抑制菌絲與孢子的雙重效果，在炭疽病的防治上是一有利選項，但須注意田間病原菌抗藥性族群之發展。

又，芒果菌株 MC3 的分生孢子及菌絲生長相較於其他菌株對部分殺菌劑表現完全或局部感受性，可能係該菌株源自非商業栽培之藥毒所試驗果園，因少接觸各種殺菌劑所致；而 MC6 菌株源自農業試驗所鳳山分所品種園亦有類似現象，多種藥劑處理後之分生孢子發芽率相對較低 (表五、七)，此亦佐證殺菌劑的頻繁使用會促進田間病原菌抗藥性族群之發展。雖然在抗藥性管理的實務上，多認為一種藥劑連續且長期使用易導致病原菌族群對該藥劑產生抗藥性。但本研究顯示，無論是二硫代胺基甲酸鹽類藥劑 (dithiocarbamates) 或其他類別的有效藥劑以至於撲克拉系列藥劑等，均為臺灣地區長期用於防治果樹炭疽病的殺菌劑，卻並未使病原菌族群產生顯著的抗藥性。即以撲克拉為例，1980 年代初期即已進行葡萄晚腐病菌對其之抗藥性調查⁽¹³⁾，1990 年代末期對芒果炭疽病菌也作過類似調查⁽³⁶⁾，而本研究之採樣年代與前者又差了近 20 年，儘管作物與採集地不同，但明顯的抗藥性族群並未產生。著者曾於田間訪談農友，得知該藥劑至今仍是防治葡萄晚腐病及芒果炭疽病的有效藥劑，頗受農友肯定。事實上，就果樹炭疽病防治藥劑而言，不易產生抗藥性的藥劑種類很多元，包含單點及多點作用機制藥劑，雖然多點

作用機制藥劑較多，但單點作用機制藥劑亦不罕見。這些不易產生抗藥性的所謂低風險藥劑是否其化學結構具特殊性，頗值得探究。如果能獲知其原因，並應用於新藥劑的開發，以避免病原菌產生抗藥性，這對於解決病害問題，減少農藥使用，以及維護環境安全都將極有助益。

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Molecular Identification and Fungicides Sensitivity of *Colletotrichum* Isolates from Various Fruit Crops in Taiwan

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Abstract

Duan, C. H., Pan, H. R., and Wang C. C. 2019. Molecular identification and fungicides sensitivity of *Colletotrichum* isolates from various fruit crops in Taiwan. Taiwan Pestic. Sci. 6: 71-104.

Anthrachnose caused by *Colletotrichum* spp. is a prevalent and severe disease on fruit crops in Taiwan. For years, fungicides have been mainly used for controlling this disease and the resistant isolates seem increasingly widespread and thus need to be investigated for managing resistance. Twelve *Colletotrichum* isolates from mango (targets for major uses of fungicides) and the other 12 isolates respectively from avocado, banana, Indian jujube, fig and strawberry (targets for minor uses of fungicides) were tested *in vitro* to determine their sensitivity to 33 anthracnose-controlling fungicides. Based on conidial morphology, 23 isolates were *C. gloeosporioides* species complex and only one was *C. acutatum* species complex. Species identification of these isolates by using polygenic sequences of ITS, GAPDH, ACT, TUB2 and ApMat revealed that *C. asianum* (9 isolates) was the dominant species of mango isolates, while *C. siamense* (2) and *C. scovillei* (1) were also found. In addition, *C. fructicola* (3), *C. musae* (1), *C. siamense* (5), *C. theobromicola* (1) and *C. tropicale* (2) composed the species of the 12 isolates from other five fruit crops. With their use rates, the effective fungicides to inhibit conidial germination were different from those to inhibit mycelial growth. In conidial germination test, dithianon, fluazinam, iminoctadine triacetate, mancozeb, metiram, oxine-copper, polyoxins and propineb were effective to inhibit the vast majority of tested isolates, while azoxystrobin, Bordeaux mixture, boscalid,

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carbendazim, difenoconazole, cyprodinil + fludioxonil, fosetyl-aluminium, hexaconazole, iprodione, kasugamycin hydrochloride hydrate, kresoxim-methyl, metconazole, manganese-prochlorate, myclobutanil, prochloraz, pyraclostrobin, tebuconazole, tetraconazole and thiabendazole had no effect. In mycelial growth test, only the fungicides with active ingredient of prochloraz were effective and no effect for the rest except metconazole and fosetyl-aluminium + oxine-copper for half of the mango isolates were inhibited by them. This work indicates the effective fungicides are consistent against *Colletotrichum* isolates no matter what their origins.

Key words: fruit, *Colletotrichum*, fungicide