番石榴果實揮發性成分之萃取分析鑑定及其對東方果實蠅之誘引性

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摘　要

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番石榴果實中揮發性成分經以固相微量萃取法（SPME）萃取，再經 GC 與 GC-MS 分析鑑定結果含有 24 種主要成分，其中含量佔 1% 以上者依大小順序為：hexanal 32.97% 、Z-3-hexenyl acetate 12.19% 、Z-3-hexenal 7.29% 、ethyl butyrate 6.18% 、ethyl acetate 6.14% 、β-caryophyllene 5.01% 、acetone 4.04% 、ethyl hexanoate 2.88% 、β-pinene 2.43% 、ocimene 2.09% 、hexyl acetate 1.93 % 、E-2-hexenal 1.81% 、及 butanal 1.45% 等 13 種化合物。而 ethanol、acetone 、ethyl acetate 、2-ethylfuran 、toluene 、α-pinene 、β-pinene 、limonene、及 cineol 等 9 種成分是首次以 SPME 方法萃取分析所得。室外網室內檢測番石榴果實揮發性成分對果實蠅雌、雄成蟲之誘引性，以 ethyl acetate 及 β- caryophyllene 最具誘引性。依據番石榴果實中揮發性成分調配而成的複成分配方中，以 Yen-C、Yen-G、Yen-H、Yen-K、Yen-M、Yen-O 等配方對果實蠅雌、雄成蟲較具誘引性，且與單成分 ethyl acetate 誘引性無顯著性差異。另 JGS1、JGS3、JGS7 配方的誘引性又較 Yen-C 及 ethyl acetate 高約 2-3 倍。50% 糖蜜溶液中添加 3% ethyl acetate 或 Yen-C 可增加 50% 糖蜜溶液的誘引力達 2 倍以上，目前該配方於田間頗具應用潛力。

（關鍵詞：東方果實蠅、番石榴揮發性成分、誘引劑、誘引性）

緒 言

東方果實蠅（*Bactrocera dorsalis* (Hendel)） 是東南亞及環太平洋地區重要的果樹害蟲，在台灣其為害的果樹種類有 50 餘種，其中又以番石榴、楊桃、芒果、蓮霧、柑桔、枇杷、桃、梨、李等經濟果樹受害最為嚴重（15）。果實蠅在台灣周年皆可見其為害，成蟲產卵於果皮內，幼蟲蛀食果肉，使果實畸形或腐爛，不堪食用，影響各種水果之產量與品質甚鉅，甚且造成我國水果外銷檢疫之難題（7, 15）。

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果實蠅的防治往昔曾採用藥劑防治、釋放不孕性昆蟲、清園與套袋法、含毒甲基丁香油滅雄法，以及含毒蛋白質水解物或糖蜜等食物誘殺法，惟各種防治方法各有優缺點，且常會引發不良副作用，包括抗藥性與殘毒問題、套袋工資成本高昂、甲基丁香油是致癌物質、食物誘引劑本身誘引距離短等問題。尤其甲基丁香油已知具基因致變異性[23, 24]，且對大、小鼠毒理試驗屬致癌物質[18, 20]，長期使用是否造成人體慢性毒害有待探討，又甲基丁香油只能誘殺雄成蟲，對直接產卵危害果實的雌成蟲却無直接誘殺的作用，常使果園在結果期間，果實蠅族群密度升高時，無法立即有效的降低果實被害率，因此，如果能發展出可同時誘殺雌成蟲與雄成蟲的誘引劑，將可有效地降低果實蠅田間族群密度，減少果實被害率。

自然環境中，果實蠅會受到各種果實中散發出來的氣味所引誘前來取食、產卵，因此，如果能夠萃取分離並分析鑑定果實中所含揮發性成分，並檢測出其中有效的誘引物質，將可研發出對雌成蟲與雄成蟲均可誘殺的誘引劑配方，對增強果實蠅的防治成效將有助益。以往即有許多報告稱多種果樹的花和果實對果實蠅雌成蟲具強烈之誘引性[3, 5]，如番石榴（*Psidium guajava* Linn.）成熟的果實具有特殊之香味，似香蕉的氣味，能引誘果實蠅；Chiu[6]曾報告番石榴中的成分 ethyl benzoate 對果實蠅雌成蟲具強烈之產卵誘引性，但無法於田間實際誘引果實蠅[8, 12]。Shieh[25]則報告多種果實之共同組成分中，以 ethyl acetate、acetaldehyde（乙醛）及 diethyl phthalate 等三種成分對果實蠅雌成蟲較具誘引力。Light & Jang[14]則報告(E)-2-hexenal 及 10-undecenal（10-十一烯醛）可對果實蠅雌成蟲之觸角引發最大的電位反應，但室內生物檢定結果無強烈誘引性[12]。

本文報導近年來靜宜大學從事番石榴果實中揮發性成分之萃取與分析鑑定研究成果，以及藥毒所檢測水果中揮發性成分之單成分與各種複成分配方對果實蠅的誘引效果，同時探討未來於田間應用的相關問題，期能開發可資應用的誘殺雌成蟲技術，以取代甲基丁香油之可能性，以改進果實蠅防治技術，提昇果實蠅防治成效，促進殺蟲劑安全合理使用。

材 料 與 方 法

番石榴果實揮發性成分之萃取與分析鑑定

供試化學品種類與純度及來源詳如表一。供試番石榴為新世紀品種，購自彰化縣社頭鄉。番石榴揮發性成分之萃取採用固相微量萃取法(Solid-phase microextraction method, SPME)，係將 5 g 黃熟的番石榴果實以刀切碎，加蒸餾水 1 mL 磨成漿汁，倒入內置有小磁石的 8 mL 血清瓶內(Serum bottle)，再將 SPME 的吸附針管(SPME fiber) 75 μm Carboxen/polydimethylsiloxane (black)，以手動方式插入前述血清瓶溶液上方(圖一)，將上述血清瓶置於水浴並以攪拌電熱板加熱。SPME 的吸附針管在 25 ℃下維持 50 分鐘，以吸附血清瓶內番石榴

果實的揮發性成分。其後將 SPME 的吸附針管拔除並移轉插入氣相層析儀(GC)或聯結質譜儀(MS)的注射口，注射口溫度設定爲 250 ℃並維持 2.5 分鐘，以進行成分脫附及分析鑑定。

使用的氣相層析儀爲 HP-5890 Series II，儀器條件如下:檢出器爲火焰離子化檢出器(Flame ionization detector, 簡稱 FID)，毛細層析管有二種，一爲內徑 0.32 mm，長 30 m 之 HP-5 column coated with a 0.25 μm film of 5% phenyl substituted methyl polysiloxane；另一爲內徑 0.2 mm，長 25 m 之 Carbowax 20M column coated with a 0.2 μm film of polyethylene glycol。注入器溫度爲 250 ℃；層析管起始溫度 35 ℃，維持 5 分鐘，每分鐘升溫 2 ℃至 120 ℃，再每分鐘升溫 10 ℃至 210 ℃並維持 5 分鐘；檢出器溫度爲 250 ℃。分流比率(Split ratio)於分析 SPME 樣品時爲無分流(splitless) ，但進行校正曲線與回收率分析時分流比率爲 1:16。層析管流速爲 1.6 mL/min。注入口聯結管(SPME Liner)爲 99 mm × 5 mm OD × 0.75 mm ID (Splitless, Supelco Co.)。

使用氣相層析質譜儀爲 HP-5890A GC-59TIA MSD，儀器條件如下: 檢出器爲四極質譜偵測儀（Quadrapole mass spectrometer）。毛細層析管有二種如上述氣相層析儀者。注入器溫度爲 250 ℃；層析管溫度如上述氣相層儀者。檢出器溫度爲 250 ℃。分流比率爲無分流(splitless)。層析管流速爲 0.6 mL /min。注入口聯結管(SPMＥ Liner)爲 99 mm × 5 mm OD × 0.75 mm ID (Splitless, Supelco Co.)。自動質譜掃描範圍（Automatic scanning in the mass range）爲 m/z 20-300 amμ。樣品的 GC 滯留時間及 GC-MS 滯留時間與質譜與已知標準品者比對，並以質譜搜尋資料庫 NBS75 K 比對，以確認各成分及其分子量。

番石榴果實中揮發性組成分配方之調配與模擬

依據以 SPME 萃取及經 GC 與 GC-MS 分析鑑定所得番石榴果實揮發性組成分與各組成分含量及比例，以購買標準品配製成各種複成分配方，以供檢測對果實蠅之誘引活性。

番石榴果實揮發性單成分及不同複成分配方對果實蠅之誘引效果

供試之果實蠅：試驗所需之果實蠅係取自前商檢局台中分局，於溫度 25～28℃、相對濕度 60～80% 及 12 小時光照（345±146 lux）之養蟲室內，依照 Chiu [4] 報告之果實蠅大量飼育方法，以人工飼料飼育果實蠅。成蟲羽化後立即分辨雌、雄性別，並分別放置於 30×30×30 ㎝之網箱內(合養者除外)，箱內放置數張打摺紙張供成蟲停留，並提供糖水與酵母粉水解物飼養成蟲備用。

供試單成分化學品來源如表一。另不同複成分配方誘引劑之組成如表四之一、二、三、四。誘餌之製作係將調配好的誘引劑 0.5mL 裝填於小塑膠管內，小塑膠管蓋子中央戳一 0.5mm 小孔，使誘引物質可散發出來。另以塑膠片製作圓筒形誘蟲盒(直徑 9cm 長 13cm)，誘蟲盒兩端開口蓋上布丁杯蓋子，蓋子上開

6 個直徑 8mm 孔洞，誘蟲盒頂部懸掛前述配製好的各種供試誘引物質(誘餌)，誘蟲盒底部則置放 13×21cm 之白色黏蟲紙。

生物檢定係於室外網室進行，網室大小為長 4m 寬 4m 高 1.7m，內置二株盆栽柑桔樹供果實蠅成蟲停留。將前述含不同供試誘引劑之圓筒形黏膠誘蟲盒(包括空白對照組)，分別懸掛於網室內圓形轉輪支架上(離地約 1.5m)，不同誘蟲盒相距約 1m。每次試驗時於下午 4:00(約日落前 2~3 小時)，釋放 200 對 14-15 日齡合養的果實蠅雌、雄成蟲，經 48 小時後檢視各種誘蟲盒誘捕蟲數，結果換算成誘殺百分率，經 arc sin$\sqrt{}$x 數值轉換後，再以 Duncan's multiple range test 統計分析比較各處理間之差異。

蛋白質水解物、糖蜜單劑或與 **ethyl acetate**、**ethyl butyrate** 及 **Yen-C** 混合之配方對果實蠅之誘引力比較

供試之蛋白質水解物購自台中縣霧峰鄉正豐化學股份有限公司，供試之糖蜜購自台中縣潭子鄉光益農化廠有限公司。將蛋白質水解物、糖蜜、ethyl acetate 先以單劑與水以不同混合比例混合，並分有或無添加 1mL 馬拉松 50%乳劑(如表九)，將前述製備的誘引劑以約 100mL 劑量置放於總收鐘形誘蟲器內底部(McPhail trap)，再依上述室外網室生物檢定法，分別檢測不同誘引劑對果實蠅之誘殺效果。另將糖蜜先與水以不同比例混合，再與 ethyl acetate、 ethyl butyrate 或 Yen-C 混合調配成不同比例配方之誘引劑(如表十及十一)，並分別於室外網室及彰化縣社頭鄉八卦山楊桃與番石榴園，檢測彼等之誘引效果。

糖蜜混合 **ethyl acetate** 配方與番石榴及不同型式誘蟲器對果實蠅誘引效果之比較

供試總收鐘形誘蟲器屬「改良型麥氏誘殺器」為台中縣霧峰鄉正豐化學股份有限公司產品，而光益船形誘蟲器則為光益農化工廠有限公司產品。將糖蜜先與水以 1:1 比例混合，再添加 ethyl acetate 3mL 組成誘引劑(如表十二)，並分有或無加置一片殺蟲藥片(供試藥片 VAPORTAPE®II 成份為 2,2-dichlorovinyl dimethyl phosphate 與 phosphate 10% 及 related compounds 0.75% ，係購自 Hercon®公司)，將前述製備的誘引劑以約 100mL 劑量置放於總收鐘形誘蟲器內底部，另以新世紀番石榴切成 2cm 丁狀 100g 做正對照組，再依上述室外網室生物檢定法，檢測比較該誘引劑與番石榴對果實蠅之誘殺效果。另外，測試比較含前述誘引劑之商品化總收鐘形誘蟲器與光益船形誘蟲器對果實蠅之誘捕效果。

結 果 與 討 論

番石榴果實揮發性成分之萃取與分析鑑定結果

番石榴果實中揮發性成分經以 SPME 方法萃取，再經 GC 以 HP-5 及 Carbowax 20M 二種分析管柱分析所得圖譜之滯留時間與面積如表二所示。進一

步以 GC-MS 相同分析管柱分析所得圖譜之滯留時間亦如表二所示。表三則顯示經分析鑑定後所得番石榴果實中含有的揮發性成分之分子量及沸點溫度。

曾比較傳統的蒸氣蒸餾溶劑萃取法(Likens-Nickersons method, LN)與真空頂空吸附萃取法(Vacuum headspace sampling method, VHS)與較新的萃取方法SPME，對番石榴果實揮發性成分之萃取效用[2]，結果顯示傳統萃取法 LN 是兼具蒸餾與萃取作用，藉蒸餾方法使樣品水蒸氣冷凝成水溶液，再藉萃取方法自水溶液中萃取樣品中的有機物質。而 VHS 萃取方法則是藉著先抽真空，再冷却的過程，以收集樣品中高揮發性物質。SPME 是較新穎簡便的萃取方法，是選擇高吸附效率的針管，利用吸附平衡的原理，自密閉容器中吸附低沸點的高揮發性物質，已被廣泛應用在蘋果揮發性香味成分萃取分析[26]，柳橙汁香味成分萃取分析[13]，及椒椒薄荷中精油組成分之萃取分析[22]。三種萃取方法中以SPME 萃取方法較佳，比較容易萃取到低沸點的化合物，且因沒有溶劑的干擾，可以萃取檢測出番石榴果實中揮發性成分 ethanol、acetone 等低沸點化合物，並可吸附到一些微量天然物成分，如α-pinene 及β-pinene。

表二顯示萃取分析所得 24 種番石榴果實揮發性成分中，含量較高成分依序爲：hexanal 32.97% 、Z-3-hexenyl acetate 12.19% 、Z-3-hexenal 7.29% 、ethyl butyrate 6.18% 、ethyl acetate 6.14% 、β-caryophyllene 5.01% 、acetone 4.04% 、ethyl hexanoate 2.88% 、β-pinene 2.43% 、ocimene 2.09% 、hexyl acetate 1.93 % 、E-2-hexenal 1.81% 、及 butanal 1.45% 等 13 種化合物，含量均佔 1% 以上。24 種揮發性成分中多數成分與前人報告番石榴果實的組成分大同小異，惟成分含量差異較大，而 ethanol、acetone、ethyl acetate、2-ethylfuran、toluene、α-pinene、β-pinene、limonene、及 cineol 等九種成分是首次以 SPME 方法萃取分析所得。Stevens *et al.*[22] 曾報告番石榴汁中主要的揮發性成分爲 C_6 的醇類（Alcohols）及醛類（Aldehydes）；Nishimura *et al.*[19] 分析番石榴果實成分含量，分析出 122 種單體化合物，主要是 C_6 的醛類、醇類及酸類（Acids）物質。Wilson & Shaw[30] 及 Ekundayo[11] 指出β-caryophyllene 爲含量最多之揮發性成分，Vernin *et al.*[29] 則報導在埃及品系番石榴揮發性氣味中的主要的成分，包括 Z-3-hexenyl acetate，Z-3-hexen-1-o1，pantan-2-one（甲基丙基酮或戊二酮），cinnamyl alcohol，3-phenyl propyl acetate，及 3-phenyl propyl alcohol（3-苯基丙醇）等。Chyau[9] 及 Yen[31] 發現 ethyl hexanoate 和 Z-3-hexenyl acetate 爲成熟番石榴主要的揮發性成分。Paniandy *et al.*[21] 曾以 SPME 方法自番石榴中萃取並分析鑑定出 73 種揮發性成分，其中二種主要揮發性物質爲hexanal 佔 65.9% ，及β-caryophyllene 佔 24.1% 。

番石榴果實中揮發性組成分配方之調配與模擬

依據以 SPME 萃取及經 GC 與 GC-MS 分析鑑定所得番石榴果實揮發性組成分與各組成分含量及比例資料，以購買的化學品及部分自行合成的化學品，調配成各種複成分配方，以供檢測對果實蠅之誘引活性。配製成各種供試複成

分配方如表四之一、二、三、四，表中各種配方依前述分析鑑定結果，部分參考原始報告，及每次誘引性檢測結果逐漸改進調配而成。

番石榴組成分單成分及複成分配方對果實蠅之誘引效果

室外網室內檢測番石榴組成分中單成分配方對果實蠅之誘引效果測試結果如表五。表五之一顯示多種供試單成分配方中，以β-caryophyllene、ethyl butyrate、 ethyl acetate、methyl acetate 及 ethyl propionate 對果實蠅雌、雄成蟲較具誘引力，其中又以 ethyl acetate、β-caryophyllene 的誘引力較佳，較複成分配方 Yecn-C 及 Yen-M 的誘引率稍高，唯不具顯著性差異(表五之二)。

Cosse *et al.*[10] 曾利用 GC 與 GC-MS 及觸角電位圖譜技術（Electroantennograph，EAG）互相配合來分析芒果中的組成分，並檢測對地中海果實蠅（Mediterranean fruit fly, *Ceratitis capitata*）觸角的反應，結果顯示（1S）-（-）-β-pinene（（1S）-（-）-β-蒎烯）及β-caryophyllene 對雌成蟲的觸角較雄成蟲更有效應。Shieh[25] 曾挑選 14 種果實共同的 30 種成分，檢測對果實蠅之誘殺效果，結果以 ethyl acetate、acetaldehyde 及 diethyl phthalate 等 3 種單成分最具誘引效果。Liu & Hwang (2000a)[16] 報告番石榴、芒果、柑桔及楊桃 4 種果實共同具有的 21 種成分，檢測對果實蠅之誘引性，結果以 methyl anthranilate（胺茴酸甲酯）、α-terpineol (L 型萜品醇)、ethyl acetate、ethyl butyrate 及 cinnamyl alcohol（肉桂醇）等 5 種單成分最具誘引效果。本試驗結果則顯示 diethyl phthalate 對果實蠅雌成蟲的誘引性較 ehtyl acetate、β-caryophyllene、ethyl butyrate 等為差；另亦曾檢測 acetatldethyde 對果實蠅之誘引性，唯該化合物沸點太低，為 20-21 ℃，在常溫下即快速揮發，故未能得知該化合物的誘引性。

早期室外網室內檢測比較番石榴與鳳梨果實及山刺番荔枝葉片之萃取液組成分配製而成的複成分配方，對果實蠅之誘引效果測試結果如表六。表六結果顯示依據番石榴萃取液成分製備而成的 G-1~G-4 複成分配方對果實蠅雌成蟲的誘引力，不亞於番石榴單成分 ethyl acetate 與 β-caryophyllene 及複成分配方 Yen-C，且彼此之誘引力間無顯著性差異。又前述單成分或複成分配方對果實蠅雌、雄成蟲之誘引力，顯著較依鳳梨果實與山刺番荔枝葉片之萃取液配製而成的誘引劑者為強(表六)，因此，往後研究著重番石榴萃取液成分誘引性試驗。

進一步於室外網室內檢測番石榴組成分複成分配方對果實蠅之誘引效果測試結果如表七。表七之一中第一次試驗結果顯示 Yen-A、B、C 三種不同配方對果實蠅雌、雄成蟲之誘引力並無顯著性差異，但 Yen-C 配方似乎較 Yen-A 及 B 配方對果實蠅雌、雄成蟲更具有誘引性(表七之一)，因而單獨試驗 Yen-C 配方之誘引力。第二次試驗結果顯示 Yen-C 配方之誘引力約為空白對照組的 2.8 倍，第三次試驗結果則顯示 Yen-A+B+C 配方之誘引力約為空白對照組的 5.8 倍(表七之一)，第四次試驗結果仍然顯示 Yen-C 配方之誘引力較佳且穩定性高，

因此，往後試驗常以 Yen-C 配方做爲正對照組，以便與其他誘引劑配方比較誘引力大小。第五、六及七次試驗結果顯示 Yen-C 配方較 Yen-D、E、F 配方之誘引力爲佳。表七之二中第八次試驗結果顯示 Yen-C、G、H 配方之誘雌百分率介於 10.9~14.0%之間，較空白對照組者(0.2%)具顯著性差異；Yen-C、G、H 配方之誘雄百分率則介於 4.5~6.3%之間，較空白對照組者(0.8%)亦具顯著性差異(表七之二)。表七之二中第九至十二次試驗結果顯示多種供試複成分配方中，以 Yen-C、Yen-K、Yen-M、Yen-O 四種配方之誘雌百分率介於 13.8~25.0%之間，較空白對照組者(0.3~0.6%)具顯著性差異；Yen-C、K、M、O 配方之誘雄百分率則介於 4.7~15.7%，較空白對照組者(0.2~1.2%)亦具顯著性差異。因而推測前述諸種配方中應具有誘引果實蠅雌、雄成蟲之成分，如能對配方之組成分再作修正以提高誘引力，並進一步於田間試驗確認其誘引力，則頗具實用性。

再進一步依據番石榴果實成分分析鑑定結果，調配更能摸擬果實中各成分的真實比例的配方，並於室外網室以轉盤法檢測各種改進配方對果實蠅之誘引效果，測試結果如表八。表八之一結果顯示第一至六次檢測結果顯示多種供試複成分配方中，以 JGS1、JGS3 及 Yen-C 三種配方對果實蠅雌、雄成蟲較具誘引力，尤其是 JGS1 配方之誘引力較 JGS4、Yen-C 及 ethyl acetate 者高 2-3 倍以上，值得進一步深入研究。持續調配各種誘引劑配方並檢測比較各種誘引劑的誘引力，結果顯示 JGS1 配方之誘引力確實較 Yen-C、ethyl acetate 及其他配方者高 2-3 倍以上，唯 JGS7 配方之誘引力則與 JGS1 相當，且無顯著性差異(表八之二)。

蛋白質水解物、糖蜜單劑或與 ethyl acetate、ethyl butyrate 及 Yen-C 混合之配方對果實蠅之誘引力比較

表九網室試驗結果顯示糖蜜對果實蠅雌、雄成蟲之誘引力較其他供試誘引劑爲強，其次者爲 ethyl acetate，蛋白質水解物之誘引力顯然不及前二者，而水亦能吸引果實蠅前來飲食，唯需添加殺蟲劑始能誘殺果實蠅。經多次試驗結果顯示糖蜜與水以 1:1 之混合比例配方對果實蠅雌、雄成蟲均具誘引力；該配方再添加微量的 ethyl acetate 較添加 ethyl butyrate 之誘引力爲佳，且可增加 2 倍的誘引力；即糖蜜、水及 ethyl acetate 三者以 50:50:3 之混合比例，對果實蠅雌、雄成蟲之誘引力最佳，且較糖蜜與水混合者之誘引力高約 2 倍(表九及十)；另該配方添加馬拉松會降低誘引力，此似與添加的殺蟲劑的氣味有關。

初步於番石榴園試驗蛋白質水解物、糖蜜單劑或與 ethyl acetate 及 Yen-C 混合之配方於田間對果實蠅之誘引性，試驗係於果園懸掛含各種供試誘引物資之總收鐘形誘蟲器各一個，每三週調查誘捕果實蠅蟲數並更新供試誘引物資，結果亦顯示糖蜜添加微量的 Ethyl acetate 確實可增加糖蜜單劑的誘引力(表十一)，未來該誘引劑配方應具田間應用潛力，唯本次田間試驗結果亦顯示蛋白質水解物亦具相當的誘引力，與網室試驗部分結果稍有差異，有待將來深入探討原因。

糖蜜（Molassess）爲製糖過程中之副產物，可做爲飼料與有機肥料添加物等用途，價格便宜，因含豐富的蔗糖、還原糖等營養成分，爲果實蠅與瓜實蠅(Melon fly, *Bactrocera cucurbitae* Coquillett.)所偏好的食物，因而具有良好的誘引效果。台灣早在 1912 年，日人多田即以糖蜜加亞砒酸鉛來誘殺果實蠅[1]，

後來 Tao 於 1952 年亦利用 91g 糖漿＋水 900mL＋3g 氟矽酸鈉來誘殺果實蠅[28]，並認爲若再添加各種果汁，其誘殺效果更好。Liu ＆ Hwang[17]報告亦指出 50% 糖蜜與等比例的 ethyl acetate 及 ethyl butyrate 的混合物以 100：1 比例混合時，於網室檢測對果實蠅的誘引力較單獨 50% 糖蜜者有高約 2 倍的誘引力，其於楊桃園的誘引力則爲 50% 糖蜜的 4.5 倍；又 50% 糖蜜添加 ethyl acetate 與 ethyl butyrate 的混合物對果實蠅誘引持效性，於 6 日內的誘引率維持在 60% 以上，至第 10 日仍維持 45~55% 之間，顯示 ethyl acetate 與 ethyl butyrate 添加於 50% 糖蜜後，確可大幅提高 50% 糖蜜的誘引力，且有效期可維持 10 日以上。

糖蜜混合 ethyl acetate 配方與番石榴及不同型式誘蟲器對果實蠅誘引效果之比較

表十二結果顯示金煌鐘形誘蟲器分別含糖蜜 50mL＋水 50mL＋ethyl acetate 3 mL 之配方與番石榴切丁 100g＋藥片者對果實蠅雌成蟲均有顯著之誘引力，其誘雌百分率分別爲 21.8 及 25.3%，二者間無顯著性差異；另外，糖蜜 50mL＋水 50mL＋ethyl acetate 3 mL 之配方對果實蠅雄成蟲之誘蟲百分率爲 26%，較其他配方具有顯著的誘引力，因此，糖蜜 50mL+水 50mL+ethyl acetate 3 mL 之配方的誘引力不亞於天然番石榴果實的誘引力(表十二)；又該配方添加殺蟲劑會降低誘引力，此似與添加的殺蟲劑的氣味有關。表十三結果再次顯示糖蜜 50mL+水 50mL+ethyl acetate 3mL 的配方對果實蠅之誘引力較不添加 ethyl acetate 者高約二倍，且使用鐘形誘蟲器來盛裝誘引劑較船形誘蟲器更具誘殺效果，該誘引劑配方搭配鐘形誘蟲器頗具田間應用潛力。

綜合以上試驗結果顯示，以 SPME 萃取分析得的 24 種番石榴果實揮發性成分中，含量較多的成分 β- caryophyllene、ethyl acetate、及 ethyl butyrate 較其他成分對果實蠅雌、雄成蟲亦具顯著性誘引性，此結果與前人報告部分吻合。由番石榴果實成分組成的複成分配方較由山刺番荔枝葉或鳳梨果實組成分的配方，對果實蠅雌、雄成蟲更具顯著性誘引性。複成分配分中，以 Yen-C、G、H、K、M、O 等配方對果實雌、雄成蟲較具誘引性，且與單成分 ethyl acetate 者無顯著性差異；進一步試驗則又顯示 JGS1、JGS3、JGS7 複成分配方的誘引性又較 Yen-C 及 ethyl acetate 高約 2-3 倍。未來依據化學分析所得番石榴果實中揮發性成分及目前調配並檢測具誘引性複成分配方資料與結果，將可再調配改進複成分配方的誘引性。又傳統 50% 糖蜜溶液中添加 3% ethyl acetate 可增加原始糖蜜溶液的誘引力達 2 倍以上，且與新鮮番石榴果實的誘引力相當，誘引持效期可達 10 日以上，於田間試驗亦具相同效果，前人報告亦有類似結果，故目前該混合配方應值得於田間廣泛應用，用來誘殺直接爲害果實的果實蠅雌成蟲，將可改進果實蠅防治成效。

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ABSTRACT

Hwang, J. S.[1*], Yen, Y. P.[2], Chang, M. C.[2], and Liu, C. Y.[1] 2002. Extraction and identification of volatile components of guava fruits and their attraction to Oriental fruit fly, *Bactrocera dorsalis* (Hendel). Plant Prot. Bull. 44：279-302. ([1]Taiwan Agricultural Chemicals and Toxic Substances Research Institute, Council of Agriculture, Wufeng, Taichung, Taiwan 413, ROC; [2]Department of Applied Chemistry, Providence University, Shalu, Taichung, Taiwan 433, ROC)

The volatile organic components of ripe guava fruit were extracted by solid phase micro-extraction（SPME）and subsequently analyzed and identified by GC and GC-MS to develop attractant formulations for female adults of Oriental fruit fly, *Bactorcera dorsalis*（Hendel）. Results showed that 24 components were identified from guava fruits, and among them, the contents with more than 1% composition were in the following order of decreasing quantity: hexanal 32.97% , Z-3-hexenyl acetate 12.19% , Z-3-hexenal 7.29% , ethyl butyrate 6.18% , ethyl acetate 6.14% , β-caryophyllene 5.01% , acetone 4.04% , ethyl hexanoate 2.88% , β-pinene 2.43% , ocimene 2.09% , hexyl acetate 1.93% , E-2-hexenal 1.81% , butanal 1.45% etc. Nine components of ethanol, acetone, ethyl acetate, 2-ethylfuran, toluene, α-pinene, β-pinene, limonene, and cineol were extracted for the first time from guava fruit by the SPME method. According to bioassay results in the net house, the single component of either ethyl acetate or β-caryophyllene more effectively attracted female and male adults of the Oriental fruit fly than any other single component. The formulations, such as Yen-C, Yen-G, Yen-H, Yen-K, Yen-M, and Yen-O prepared from multiple components, were found to be more attractive than other formulations. However, in a comparison with ethyl acetate, their attractions were showed no significant differences among themselves. Recently, three new formulations, JGS1, JGS3, and JGS7, each was found to have three-fold higher attraction than that of either Yen-C or ethyl acetate. Since they are potentially effective attractants, their modified formula and bioassays need to be further studied. Fortunately, a new formulation was also developed as 3% ethyl acetate or Yen-C added into a 50% molasses solution. The attraction was increased to two-fold over the 50% molasses solution by itself, and this novel and effective formulation will be recommended for use in controlling the Oriental fruit fly in the field.

(Key words： Oriental fruit fly, *Bactrocera dorsalis*, volatile components of guava fruit, attractant, attraction)

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圖一、固相微量萃取法之裝置。

Fig. 1. The equipment of solid-phase micro-extraction method.

表一、供試化學品種類與純度及來源

Table 1. The purity and origin of tested chemicals

Chemicals in Chinese	Chemicals in English	Purity (%)	Company
乙醚	Ether	＞99	Merk
戊烷	Pentane	＞99	Merk
己烷	Hexane	＞99	Merk
乙醇	Ethanol	＞99	Merk
丙酮	Acetone	＞99	Merk
二氯甲烷	Dichloromethane	＞99	Merk
乙酸乙酯	Ethyl acetate	＞99	Merk
甲苯	Toluene	＞99	Merk
辛酸乙酯	Ethyl octanoate (caprylate)	＞99	Merk
己醛	Hexanal	＞98	Aldrich
丁酸乙酯	Ethyl butyrate (butanoate)	＞99	Aldrich
己醇	Hexanol	＞99	Aldrich
β-月桂油烯	β-Myrcene	＞70	Aldrich
檸檬油精	Limonene	＞97	Aldrich
α-橙椒烯	α-Cubebene	＞97	Aldrich
反-2-己醛	E-2-Hexenal	＞95	TCI
順-3-己烯醇	Z-3-Hexen-l-ol	＞97	TCI
α-萜品醇	α-Terpineol	＞90	TCI
α 型派烯	α-Pinene	＞95	TCI
β 型派烯	β-Pinene	＞95	TCI
己酸乙酯	Ethyl hexanoate (caproate)	＞99	TCI
順-3-己酯	Z-3-Hexenyl acetate	＞97	TCI
乙酸己酯	Hexyl acetate	＞99	TCI
桉樹腦	Cineol	＞98	TCI
乙酸苯丙酯	3-Phenylpropyl acetate	＞98	TCI
β-丁香油烴	β-Caryophyllene	＞80	TCI
3-甲硫基丙酸	3-(methylthio)propanoic acid	＞97	TCI
乙酸-2-甲基-1-丙酯	2-Methyl-1-propyl acetate	＞99	TCI
β-紫羅酮	β-Ionone	＞95	TCI
乙醯甲基甲醇	Acetoin	＞95	TCI
乙酸	Acetic acid	＞99	Showa
蘿蘇萜	Ocimene	＞50	Wei-The Co.
順-3-己醛	Z-3-Hexenal	＞70	Synthesized
月桂油烯	Myrcene	＞90	Acros
氯鉻酸吡啶	Pyridinium chlorochromate	＞98	Acros
桂皮乙酸酯	Cinnamyl acetate	＞97	Acros
苯甲醛	Benzaldehyde	＞98	Acros
苯二甲酸二乙酯	Diethyl phthalate	＞98	Acros
肉桂醇	Cinnamyl alcohol	＞98	Lancaster
苯甲酸乙酯	Ethyl benzoate	＞99	Lancaster
2-甲基丙醇	2-Methyl-1-propanol	＞99	Lancaster
苯乙烯	Styrene	＞99	Lancaster
乙酸甲酯	Methyl acetate	＞99	Lancaster

表二、番石榴果實中之揮發性成分以 SPME 法萃取並以 GC 及 GC-MS 兩種層析管柱分析所得圖譜之滯留時間與面積

Table 2. The retention time and area of volatile components of guava fruits isolated by SPME method and analysed by GC and GC-MS with HP-5 and Carbowax 20 M columns

Peak No.	Components [1)]	HP-5 column			Carbowax 20 M column		
		R_f (min)	Area (%)	R_f (min) [2)]	R_f (min)	Area (%)	R_f (min) [2)]
1	Ethanol	2.921	0.58	1.773	9.427	1.02 [c 3)]	3.634
2	Acetone	3.082	4.04	1.881	6.099	0.32	2.642
3	Methyl acetate	3.203	0.70	2.000	--	--	--
4	Butanal	3.848	1.45	2.316	--	--	--
5	Ethyl acetate	4.034	6.14	2.712	7.989	1.25	2.908
6	2-Ethylfuran	5.915	0.79	3.881	9.427	1.02 [c 3)]	3.150
7	Toluene	8.392	0.96	6.000	12.608	2.75 [d 3)]	4.901
8	Z-3-Hexenal	10.054	7.29 [a 3)]	7.292	18.199	5.31	7.422
9	Hexanal	10.139	32.97 [a 3)]	7.361	14.736	22.12 [e 3)]	5.121
10	Ethyl butyrate	10.218	6.18	7.732	12.311	1.80	4.224
11	E-2-Hexenal	13.394	1.81	10.409	23.001	2.48	10.693
12	Z-3-Hexen-l-ol	13.695	0.94	10.973	36.879	2.45	22.575
13	Hexanol	14.781	0.62	11.612	34.871	2.71	20.870
14	α-Pinene	19.078	0.48	15.674	12.608	2.75 [d 3)]	4.897
15	Benzaldehyde	21.456	0.18	17.602	45.236	0.17	31.182
16	β-Pinene	22.346	2.43	18.344	14.736	22.12 [e 3)]	5.823
17	Ethyl hexanoate	24.747	2.88	20.919	25.355	0.53	12.742
18	Z-3-Hexenyl acetate	25.388	12.19	21.510	31.630	19.14	17.600
19	Hexyl acetate	25.879	1.93	22.134	27.695	1.18	14.769
20	Limonene	26.654	0.97 [b 3)]	22.775	20.889	1.04	8.275
21	Cineol	26.854	0.44 [b 3)]	22.932	21.963	0.89	9.493
22	Ocimene	27.694	2.07	23.748	24.706	1.72	11.548
23	3-Phenylpropyl acetate	51.099	0.37	47.700	59.871	1.75	52.032
24	β-Caryophyllene	52.641	5.01	49.957	49.820	8.52	35.672

[1)] The componens were arranged by the order of retention time from HP-5 column.

[2)] The R_f (min) from GC-MS.

[3)] a, b, c, d, e mean the area was overlap, and values followed by a and b were estimated.

表三、番石榴果實中揮發性成分之分子量及沸點溫度

Table 3. The molecular weight and boiling point of volatile components of guava fruits

Peak No.	Components	M. W.	B. P. (℃)
1	Ethanol	46	78
2	Acetone	58	56
3	Methyl acetate	74	57.5
4	Butanal	72	75.7
5	Ethyl acetate	88	77
6	2-Ethylfuran	96	92
7	Toluene	92	110.7
8	Z-3-Hexenal	98	120
9	Hexanal	100	131
10	Ethyl butyrate	116	120.6
11	E-2-Hexenal	98	146
12	Z-3-Hexen-l-ol	100	157
13	Hexanol	102	157.2
14	α-Pinene	136	160
15	Benzaldehyde	106	171
16	β-Pinene	136	169
17	Ethyl hexanoate	144	167
18	Z-3-Hexenyl acetate	142	169
19	Hexyl acetate	144	169.2
20	Limonene	136	176.4
21	Cineol	154	176
22	Ocimene	136	180
23	3-Phenylpropyl acetate	178	245
24	β-Caryophyllene	204	245

表四之一、番石榴果實中揮發性成分配製成各種不同誘引劑配方之組成分比例（mL）

Table 4-1.The chemical composition ratio of different attractants prepared from volatile components of guava fruits for oriental fruit fly (mL)

No.	Components	G-1	G-2	G-3	G-4
5	Ethyl acetate	2.45	14.1	1.98	1.98
8	Hexanal	3.65	10.2	1.63	1.63
9	Ethyl butyrate	3.65	5.9	1.07	1.07
10	E-2-Hexenal	4.2	1.9	2.35	2.35
12	Hexanol	1.7	--	--	--
15	Ethyl hexanoate	0.95	3.7	--	--
16	Z-3-Hexenyl acetate	1.35	2.4	0.3	0.3
18	Cinnamyl acetate	0.85	--	0.49	0.49
20	Cineol	5.55	1.6	1.22	1.22
21	Ocimene	--	--	--	1.59
22	3-Phenylpropyl acetate	--	--	1.06	1.06
23	β-Caryophyllene	5.0	1.0	2.81	2.81
24	Ethyl octanoate	--	0.4	--	--
32	Benzaldehyde	0.25	--	--	--

表四之二、番石榴果實中揮發性成分配製成各種不同誘引劑配方之組成分比例（mL）

Table 4-2.The chemical composition ratio of different attractants prepared from volatile components of guava fruits for oriental fruit fly (mL)

No.	Components	Yen-A	Yen-B	Yen-C	Yen-D	Yen-E	Yen-F	Yen-G	Yen-H
1	Ethanol	--	--	6.36	5.31	5.31	5.31	3.18	3.18
5	Ethyl acetate	--	--	6.48	5.39	5.39	5.39	3.24	3.24
8	Hexanal	--	--	0.84	--	0.7	--	0.42	0.42
9	Ethyl butyrate	0.75	1.0	2.16	1.78	1.78	1.78	1.08	1.08
10	E-2-Hexenal	--	--	--	--	--	--	1.07	1.07
11	Z-3-Hexen-l-ol	--	--	0.24	--	0.2	--	0.12	0.12
12	Hexanol	--	--	--	--	--	--	0.1	0.1
15	Ethyl hexanoate	1.0	1.0	3.84	--	0.39	--	1.92	1.92
16	Z-3-Hexenyl acetate	--	--	0.12	--	0.1	--	0.06	0.06
17	Hexyl acetate	--	--	--	2.0	2.0	--	--	--
22	3-Phenylpropyl acetate	--	--	--	2.0	2.0	--	--	--
23	β-Caryophyllene	1.0	1.0	0.12	--	0.1	--	0.06	0.06
24	Ethyl octanoate	--	--	0.48	0.39	0.39	0.39	0.24	0.24
27	Myrcene	--	--	0.72	0.56	0.56	0.56	0.36	0.36
28	Methyl acetate	0.5	0.1	--	--	--	--	--	--
32	Acetoin	--	--	--	--	--	--	--	0.4
35	2-methyl propyl acetate	--	--	--	0.2	0.2	--	--	--
37	Benzaldehyde	--	--	--	0.2	0.2	--	--	--
38	β-Ionone	--	--	--	0.2	0.2	--	--	--

表四之三、番石榴果實中揮發性成分配製成各種不同誘引劑配方之組成分比例（mL）
Table 4-3.The chemical composition ratio of different attractants prepared from volatile components of guava fruits for oriental fruit fly (mL)

No.	Components	Yen-I	Yen-J	Yen-K	Yen-L	Yen-M	Yen-N	Yen-O	Yen-2000
1	Ethanol	3.18	3.18	6.36	0.194	--	--	--	--
5	Ethyl acetate	3.24	3.24	6.48	1.94	--	--	--	11.4
8	Hexanal	0.42	0.42	0.84	3.72	--	1.27	--	10.6
9	Ethyl butyrate	1.08	1.08	2.16	1.681	0.065	--	0.065	3.8
10	E-2-Hexenal	1.07	1.07	--	0.071	0.175	2.32	0.175	6.1
11	Z-3-Hexen-l-ol	0.12	0.12	0.24	--	2.42	2.205	2.42	3.8
12	Hexanol	0.1	0.1	--	--	0.67	0.775	0.67	3.0
13	α-Pinene	--	--	--	1.532	0.14	0.13	0.14	--
15	Ethyl hexanoate	1.92	1.92	3.84	0.24	--	--	--	16.7
16	Z-3-Hexenyl acetate	0.06	0.06	0.12	0.214	2.71	0.22	2.71	15.2
17	Hexyl acetate	--	--	--	--	0.17	--	0.17	--
18	Cinnamyl acetate	--	--	--	--	--	--	0.21	8.3
20	Cineol	--	--	--	0.568	3.825	3.8	3.825	9.1
22	3-Phenylpropyl acetate	--	--	--	--	--	1.625	--	2.3
23	β-Caryophyllene	0.06	0.06	0.12	--	0.37	3.59	0.37	3.8
24	Ethyl octanoate	0.24	0.24	0.48	--	--	--	--	3.0
25	Cinnamyl alcohol	--	--	--	--	--	--	0.27	1.5
26	α-Terpineol	--	--	--	--	--	--	1.33	1.5
27	Myrcene	0.36	0.36	0.72	0.158	--	0.145	--	--
32	Acetoin	0.4	0.4	0.8	--	--	--	--	--
33	Ethyl benzoate	0.5	--	--	--	--	--	--	--
34	2-methyl-1-propanol	--	0.14	--	--	--	--	--	--
35	2-methyl propyl acetate	--	0.08	--	--	--	--	--	--
36	Styrene	--	--	--	0.174	--	--	--	--
37	Benzaldehyde	--	--	--	--	0.735	0.13	0.735	--

表四之四、番石榴果實中揮發性成分配製成各種不同誘引劑配方之組成分比例（mL）

Table 4-4.The chemical composition ratio of different attractants prepared from volatile components of guava fruits for oriental fruit fly (mL) [1)]

No.	Components	JGS2	JGS6	JGS8	JGS9	JGS10	JGS11	JGS12
1	Ethanol	6.6	--	--	1.0	--	--	--
2	Acetone	1.3	--	0.1	--	1.0	--	--
3	Dichloromethane	--	--	0.2	--	1.0	--	--
4	Acetic acid	--	--	--	1.0	--	--	--
5	Ethyl acetate	13.1	--	0.1	1.0	--	2.0	0.2
6	Toluene	6.6	1.0	0.2	--	--	--	--
7	Z-3-Hexenal	--	--	3.9	--	--	--	1.6
8	Hexanal	10.8	--	3.9	--	1.0	0.4	7.2
9	Ethyl butyrate	7.1	--	--	1.0	--	0.1	0.3
10	E-2-Hexenal	15.6	1.0	62.6	--	--	1.5	2.7
11	Z-3-Hexen-l-ol	--	--	1.6	--	--	1.5	2.1
12	Hexanol	--	--	0.5	--	--	0.3	1.2
13	α-Pinene	--	--	4.6	--	--	0.03	0.3
14	β-Pinene	--	--	5.6	--	--	--	--
15	Ethyl hexanoate	--	--	--	--	--	0.1	0.1
16	Z-3-Hexenyl acetate	2.0	--	--	--	1.0	0.1	2.5
17	Hexyl acetate	--	--	--	--	--	--	0.1
18	Cinnamyl acetate	3.2	--	--	--	1.0	--	--
19	Limonene	--	--	1.3	--	--	0.2	0.24
20	Cineol	8.1	1.0	5.6	--	--	0.5	0.6
21	Ocimene	--	--	--	--	--	1.7	0.6
22	3-Phenylpropyl acetate	7.0	1.0	--	--	--	0.2	0.1
23	β-Caryophyllene	18.6	--	0.2	1.0	--	11.3	0.6
27	Myrcene	--	--	9.7	--	--	--	--
28	Benzaldehyde	--	--	--	--	--	0.1	--

[1)] The chemical composition ratio of JGS1, 3, 4, 5, 7 were kept blank for intellectual property.

表五之一、網室內以轉盤法檢測番石榴組成分之單成分配方對果實蠅雌雄成蟲之誘引力

Table 5-1. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted	
	♀♀	♂♂
β-Caryophyllene	20.7± 8.9 c [1)]	20.5± 7.3 c
Cineol	1.4± 2.6 a	1.0± 1.4 a
Cinnamyl acetate	0.7± 0.9 a	1.4± 1.9 a
E-2-Hexenal	1.0± 1.3 a	1.0± 1.2 a
Ethyl acetate	13.1± 9.5 b	9.6± 7.2 b
Blank	0.6± 0.8 a	1.0± 1.3 a
Benzaldehyde	3.5± 4.7 ab	7.2± 5.8 bc
Z-3-Hexenyl acetate	7.0± 5.5 bc	6.1± 4.1 b
Z-3-Hexenyl-1-ol	7.3± 4.9 c	12.5± 6.2 b
α-Terpineol	1.2± 3.0 a	2.0± 4.3 a
Ethyl butyrate	20.6± 7.1 d	10.3± 4.6 bc
Blank	0.7± 0.9 a	1.7± 1.9 a
Ethyl caproate	7.1± 5.2 b	11.1± 8.1 b
Ethanol	4.3± 1.8 b	10.1± 5.0 b
Ethyl acetate	23.2± 6.2 c	16.3± 5.7 b
Diethyl phthalate	8.1± 3.6 b	16.1±11.0 b
Blank	1.1± 0.9 a	2.3± 2.2 a
Methyl benzoate	2.1± 3.4 b	3.7± 5.0 b
Methyl hexanoate	2.3± 3.3 b	2.9± 4.4 b
Methyl acetate	14.8± 8.1 a	15.8± 8.1 a
β-caryophyllene	10.5± 6.8 a	10.4± 10.2a
Ethyl butyrate	13.2± 3.3 a	10.3± 5.0 a
Blank	0.1± 0.2 c	0.7± 1.4 b

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表五之二、網室內以轉盤法檢測番石榴組成分之單成分配方對果實蠅雌雄成蟲之誘引力

Table 5-2. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted ♀♀	% of total flies attracted ♂♂
Methyl acetate	1.4± 1.4 bc[1)]	2.4± 3.6 bc
Ethyl acetate	15.5± 7.1 a	15.8± 6.8 a
Ethyl propionate	5.9± 6.2 b	4.4± 3.7 b
Ethyl butyrate	4.3± 4.7 b	2.6± 3.1 bc
β-Caryophyllene	2.7± 5.3 bc	1.4± 3.2 bc
Blank	0.2± 0.2 c	0.2± 0.2 d
Ethyl propionate	13.8± 5.0 c	14.4± 6.1 c
Ethyl acetate	14.6± 7.2 c	13.3± 5.9 c
Hexan-1-01	1.2± 1.4 a	2.0± 1.7 a
(Z)-3-hexen-1-01	4.5± 3.4 b	7.1± 4.2 b
Yen-C	12.2± 2.7 c	9.4± 1.2 bc
Blank	0.9± 1.2 a	1.2± 1.9 a
β-Caryophyllene	12.8± 6.7 a	11.4± 4.8 a
Ethyl acetate	11.6± 8.9 a	10.1±11.9 a
Ethyl butyrate	8.4± 8.8 ab	5.8± 6.0 a
Diethyl phthalate	4.1± 4.6 b	6.9± 5.8 a
Yen-C	7.7± 3.1 ab	7.5± 6.0 a
Blank	0.1± 0.2 c	0.8± 0.8 b
Ethyl acetate	13.0± 5.3 b	11.8± 7.9 b
Ethyl propionate	9.4± 6.5 b	12.1±10.9 b
β-Caryophyllene	21.0± 5.9 a	32.5±14.0 a
Ethyl butyrate	7.8± 3.8 b	5.6± 3.8 bc
Yen-M	11.1± 7.1 b	3.4± 3.3 c
Blank	0.1± 0.2 c	0.1± 0.2 d

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表六、網室內以轉盤法檢測番石榴與鳳梨果實及山刺番荔枝葉萃取液組成分配方對果實蠅雌雄成蟲之誘引力

Table 6. Attraction of different attractant formulations derived from guava and pineapple fruit and soursop leaf extract components to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted	
	♀♀	♂♂
G-1	10.3 ± 8.6 a [2)]	1.4 ± 1.3 c
G-2	15.4 ± 7.1 a	3.8 ± 2.1 bc
Ethyl acetate	13.2 ± 10.7 a	9.4 ± 9.9 b
β-Caryophyllene	11.8 ± 7.5 a	29.4 ± 19.6 a
Yen-C	8.0 ± 3.9 a	3.9 ± 2.7 bc
Blank	0.1 ± 0.2 b	0.0 ± 0.0
Pineapple-1 [1)]	1.5 ± 1.8 bc	1.5 ± 1.8 bc
G-3	22.0 ± 10.8 a	11.7 ± 5.3 a
Ethyl acetate	13.4 ± 6.2 a	14.6 ± 7.0 a
Yen-C	5.0 ± 4.8 b	4.2 ± 4.6 b
Blank	0.1 ± 0.2 c	0.4 ± 0.6 c
Soursop leaf-1 [1)]	0.3 ± 0.4 b	0.2 ± 0.3 c
G-3	13.7 ± 12.5 a	6.2 ± 6.0 b
Ethyl acetate	11.6 ± 8.2 a	13.3 ± 5.8 a
Yen-C	12.3 ± 8.3 a	10.1 ± 4.9 a
Blank	0.4 ± 0.7 b	0.3 ± 0.5 c
G-4	7.0 ± 6.3 a	3.1 ± 1.9 b
G-3	8.2 ± 6.7 a	4.4 ± 3.7 b
Ethyl acetate	10.0 ± 8.6 a	9.5 ± 6.7 a
Yen-C	6.1 ± 4.4 a	5.3 ± 3.3 ab
Blank	0.1 ± 0.2 b	0.4 ± 0.7 c

[1)] The chemical composition ratio of Pineapple-1 and Soursop leaf-1 refered to Chang report [(2)].

[2)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表七之一、網室內以轉盤法檢測番石榴組成分之複成分配方對果實蠅雌雄成蟲之誘引力

Table 7-1. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Trial No.	Attractants	% of total flies attracted	
		♀♀	♂♂
I	Yen-A	8.2± 4.8 a [1)]	4.4± 2.2 a
	Yen-B	7.2± 3.0 a	11.0± 2.6 b
	Yen-C	13.2± 7.8 a	10.6± 6.7 ab
	Blank	6.4± 2.1 a	7.4± 3.9 ab
II	Yen-C	23.3±13.1 b	13.7±10.2 a
	Blank	8.2± 2.9 a	7.0± 4.0 a
III	Yen-A+B+C	21.7±10.7 b	9.9± 5.9 b
	Blank	3.7± 3.0 a	6.3± 5.6 a
IV	Yen-C	23.0±14.3 c	11.5±10.8 b
	H1=1A+1B+2C	12.1±11.9 b	2.9± 4.3 a
	H2=1A+2B+1C	2.5± 1.9 a	2.1± 2.9 a
	H3=2A+1B+1C	4.9± 4.4 ab	3.7± 4.4 a
	Blank	1.1± 2.2 a	3.5± 4.3 a
V	Yen-C	22.3±12.5 c	10.2±11.4 b
	Yen-D	2.7± 2.9 ab	0.8± 1.0 a
	Yen-E	4.2± 3.0 b	1.8± 1.4 a
	Blank	0.4± 1.0 a	0.4± 0.9 a
VI	Yen-C	15.5± 7.0 c	5.6± 2.2 b
	Yen-F	6.0± 6.9 b	4.6± 3.8 b
	Blank	0.2± 0.4 a	1.8± 2.0 a
VII	Yen-C	13.0± 3.1 b	6.9± 3.2 a
	Yen-C+D+E	9.1± 4.2 b	4.4± 4.9 a
	Yen-C+D+E+F	10.1± 9.3 b	2.9± 3.1 a
	Blank	2.0± 2.4 a	3.4± 2.8 a

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表七之二、網室內以轉盤法檢測番石榴組成分之複成分配方對果實蠅雌雄成蟲之誘引力

Table 7-2. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Trial No.	Attractants	% of total flies attracted	
		♀♀	♂♂
VIII	Yen-C	13.7± 8.2 b [1)]	6.3± 4.8 b
	Yen-G	10.9± 8.7 b	4.5± 2.3 b
	Yen-H	14.0±10.7 b	5.2± 3.9 b
	Blank	0.2± 0.6 a	0.8± 1.7 a
IX	Yen-C	14.8±12.8 c	6.1± 5.9 c
	Yen-I	6.2± 3.7 b	2.0± 2.0 ab
	Yen-J	6.4± 5.0 b	2.9± 3.7 b
	Blank	0.4± 0.7 a	0.2± 0.5 a
X	Yen-C	21.3±12.6 b	15.7±11.0 b
	Yen-K	25.0±15.2 b	15.7± 7.0 b
	Blank	0.3± 0.5 a	1.2± 2.8 a
XI	Yen-C	7.4± 5.1 b	6.6± 4.5 b
	Yen-L	8.3± 3.8 b	5.8± 2.5 b
	Yen-M	13.8± 7.2 b	4.7± 3.1 b
	Yen-N	7.3± 5.6 b	4.8± 2.5 b
	Blank	0.4± 0.7 a	1.0± 0.8 a
XII	Yen-C	12.0± 6.2 b	13.5±11.1 c
	Yen-M	15.2± 5.9 b	5.9± 2.3 b
	Yen-O	14.6± 5.2 b	5.0± 2.7 b
	Blank	0.6± 1.0 a	0.8± 0.9 a

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表八之一、網室內以轉盤法檢測番石榴組成分之複成分配方對果實蠅雌雄成蟲之誘引力

Table 8-1. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Trial No.	Attractants	% of total flies attracted	
		♀♀	♂♂
I	JGS1	8.6 ± 10.0 a [1)]	7.6 ± 9.5 a
	Ethyl acetate	3.4 ± 3.9 ab	3.3 ± 4.1 ab
	Yen-C	2.4 ± 4.0 b	1.3 ± 1.3 ab
	Blank	0.1 ± 0.2 c	0.3 ± 0.5 b
II	JGS1	3.6 ± 6.1 a	2.2 ± 2.6 ab
	JGS2	0.8 ± 1.4 bc	0.2 ± 0.4 c
	Ethyl acetate	7.1 ± 9.2 a	4.7 ± 4.3 a
	Yen-C	3.8 ± 4.7 ab	2.1 ± 3.2 b
	Blank	0.1 ± 0.2 c	0.1 ± 0.2 c
III	Yen-2000	3.3 ± 3.5 b	2.8 ± 1.0 b
	JGS1	14.4 ± 4.9 a	8.6 ± 2.8 a
	Yen-C	7.8 ± 6.5 b	8.2 ± 6.9 b
	Ethyl acetate	7.4 ± 6.1 b	6.8 ± 4.9 b
	Blank	0.6 ± 0.9 c	0.8 ± 0.1 c
IV	JGS1	6.3 ± 4.4 a	4.3 ± 3.8 a
	JGS2	2.6 ± 2.5 ab	0.5 ± 0.5 ab
	JGS3	6.3 ± 4.7 a	4.3 ± 4.4 a
	Yen-C	3.9 ± 6.1 ab	3.4 ± 7.2 ab
	Ethyl acetate	5.9 ± 10.4 a	3.9 ± 6.6 ab
	Blank	0.1 ± 0.2 bc	0.1 ± 0.2 bc
V	JGS4	17.7 ± 7.4 a	10.1 ± 4.5 a
	Yen-C	4.2 ± 3.1 b	6.1 ± 4.2 a
	Ethyl acetate	6.3 ± 3.0 b	6.6 ± 3.0 a
	Blank	0.4 ± 0.2 c	0.4 ± 0.5 b
VI	JGS1	18.6 ± 9.1a	12.3 ± 7.9 a
	JGS4	4.9 ± 3.2 b	2.7 ± 1.4 b
	Yen-C	5.6 ± 7.1 b	6.6 ± 8.0 b
	Ethyl acetate	8.0 ± 7.2 b	5.7 ± 4.4 b
	Blank	0.1 ± 0.2 c	0.4 ± 0.5 c

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表八之二、網室內以轉盤法檢測番石榴組成分之複成分配方對果實蠅雌雄成蟲之誘引力

Table 8-2. Attraction of attractants derived from guava fruit components to oriental fruit fly tested by rotated wheel method in net house

Trial No.	Attractants	% of total flies attracted	
		♀♀	♂♂
VII	JGS5	9.5 ± 3.4 ab [1)]	10.0 ± 0.6 a
	JGS6	0.4 ± 0.3 c	0.3 ± 0.5 b
	JGS1	12.1 ± 5.5 a	11.6 ± 0.5 a
	Yen-C	7.4 ± 7.0 b	7.4 ± 5.2 a
	Ethyl acetate	7.3 ± 5.1 b	9.5 ± 8.1 a
	Blank	0.4 ± 0.5 c	1.3 ± 1.8 b
VIII	JGS7	9.1 ± 9.1 a	5.8 ± 5.6 a
	JGS1	7.1 ± 4.8 a	4.1 ± 2.6 a
	Yen-C	4.7 ± 2.5 ab	2.8 ± 1.4 a
	Ethyl acetate	3.1 ± 2.9 b	3.5 ± 4.2 a
	Blank	0.2 ± 0.3 c	0 ± 0
IX	JGS8	2.1 ± 1.2 b	1.3 ± 0.8 b
	JGS1	18.8 ± 9.9 a	10.0 ± 2.7 a
	Yen-C	3.4 ± 2.9 b	2.9 ± 2.4 b
	Ethyl acetate	2.0 ± 2.3 bc	1.6 ± 2.7 b
	Blank	0.2 ± 0.3 c	0.3 ± 0.5 c
X	JGS9	6.7 ± 3.2 b	13.2 ± 7.2 a
	JGS10	0.3 ± 0.5 cd	0.9 ± 0.7 c
	JGS1	12.7 ± 7.7 a	9.9 ± 3.9 ab
	Yen-C	7.4 ± 5.7 b	6.4 ± 3.9 b
	Ethyl acetate	1.4 ± 0.9 c	1.6 ± 1.9 c
	Blank	0.1 ± 0.2 d	0.3 ± 0.5 c
XI	JGS11	8.0 ± 4.9 ab	5.4 ± 3.3 b
	JGS12	5.7 ± 3.2 ab	4.4 ± 4.8 bc
	JGS7	12.5 ± 6.7 a	11.3 ± 5.0 a
	Yen-C	3.9 ± 4.1 b	2.9 ± 3.4 bc
	Ethyl acetate	3.8 ± 3.0 b	5.8 ± 4.6 ab
	Blank	0.3 ± 0.3 c	0.8 ± 0.5 c

[1)] Mean± S.D. derived from 8~10 trials. Data were transformed to arc sin $\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表九、網室內以轉盤法檢測糖蜜與蛋白質水解物及 Ethyl acetate 對果實蠅雌雄成蟲之誘引力

Table 9. Attraction of molasses, protein hydrolysates and ethyl acetate to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted	
	♀♀	♂♂
Protein hydrolysates 1mL+Water 100mL +Malathion 1mL	9.2 ± 4.8 c[1)]	6.8 ± 1.5 b
Protein hydrolysates 1mL+Water 100mL	9.9 ± 5.2 c	9.5 ± 4.4 b
Molasses 50mL+ Water 50mL+ Malathion 1mL	19.1 ± 8.0 ab	10.2 ± 3.6 b
Molasses 50mL+ Water 50mL	25.3 ± 7.6 a	18.8 ± 6.0 a
Ethyl acetate 3mL+ Water 97mL+ Malathion 1mL	15.8 ± 4.7 b	22.3 ± 9.3 a
Ethyl acetate 3mL+ Water 97mL	4.0 ± 4.1 d	2.1 ± 1.9 c
Ethyl acetate 3mL+ Water 97mL+ Malathion 1mL	21.7 ± 6.3 a	14.9 ± 6.2 a
Ethyl acetate 17mL+ Water 83mL+ Malathion 1mL	16.6 ± 6.5 ab	15.1 ± 6.1 a
Ethyl acetate 33mL+ Water 67mL+ Malathion 1mL	21.0 ± 4.5 a	15.4 ± 4.5 a
Ethyl acetate 3mL+ Water 97mL	6.0 ± 7.6 c	4.8 ± 5.6 b
Water 100mL+ Malathion 1mL	12.6 ± 16.2 bc	19.0 ± 13.5 a
Water 100mL	0.6 ± 0.5 c	0.9 ± 0.7 b
Molasses 50mL+ Water 50mL	18.9 ± 7.3 a	18.0 ± 6.3 a
Molasses 25mL+ Water 75mL	15.0 ± 5.9 ab	15.6 ± 4.8 a
Molasses 12.5mL+ Water 87.5mL	19.3 ± 9.6 a	13.6 ± 5.4 ab
Molasses 6.3mL+ Water 93.7mL	10.4 ± 3.8 b	10.9 ± 4.2 b
Molasses 3.2mL+ Water 96.8mL	9.3 ± 4.8 c	16.8 ± 6.3 a
Water 100mL	2.0 ± 1.7 d	1.8 ± 1.6 c
Molasses 50mL+ Water 50mL	13.9 ± 6.7 c	18.7 ± 3.2 a
Molasses 50mL+ Water 50mL+ Malathion 1mL	9.3 ± 4.9 d	12.6 ± 5.2 b
Molasses 50mL+ Water 50mL +Ethyl acetate 3mL	25.3 ± 8.8 a	20.7 ± 5.8 a
Molasses 50mL+ Water 50mL +Ethyl acetate 3mL + Malathion 1mL	18.7 ± 4.2 b	14.4 ± 3.8 b
Ethyl acetate 3mL+ Water 97mL+ Malathion 1mL	9.7 ± 3.7 cd	13.6 ± 4.6 b
Water 100mL	0.7 ± 0.7 e	1.5 ± 1.5 c

[1)] Mean± S.D. derived from 10~12trials. Data were transformed to arc sin$\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表十、網室內以轉盤法檢測糖蜜與 Ethyl acetate 或 Ethyl butyrate 混合之配方對果實蠅雌雄成蟲之誘引力

Table 10. Attraction of molasses mixed with ethyl acetate or ethyl butyrate to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted	
	♀♀	♂♂
Molasses 50mL+ Water 50mL	14.4 ± 14.2 bc[1)]	21.4 ± 10.8 a
Molasses 50mL+ Water 50mL+Ethyl acetate 3mL	31.4 ± 7.4 a	24.4 ± 10.7 a
Molasses 50mL+Water 50mL+Ethyl butyrate 3mL	12.3 ± 4.8 c	8.7 ± 3.8 b
Molasses 12.5mL+ Water 87.5mL	7.5 ± 5.0 bc	11.8 ± 3.4 b
Molasses 12.5mL+ Water 87.5mL+Ethyl acetate 3mL	15.4 ± 4.6 b	21.0 ± 4.0 a
Molasses 12.5mL+ Water 87.5mL+Ethyl butyrate 3mL	6.6 ± 3.1 c	7.1 ± 2.4 b

[1)] Mean± S.D. derived from 8 trials. Data were transformed to arc sin$\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表十一、於番石榴園試驗糖蜜與 Ethyl acetate 或 Yen-C 混合之配方及蛋白質水解物對果實蠅雌雄成蟲誘引力之比較

Table 11. Comparison of attraction of molasses mixed with ethyl acetate or Yen-C, and protein hydrolysates to oriental fruit fly tested in guava orchard

Attractants	Total no. of trapped flies	
	♀♀	♂♂
	1998/4/15-1999/4/14	
Protein hydrolysates 3mL+ Water 300mL + Malathion 3mL	391	417
Molasses 150mL+ Water 150mL+ Malathion 3mL	209	193
Molasses 150mL+ Water 150mL+ Ethyl acetate 6mL + Malathion 3mL	607	544
Molasses 150mL+ Water 150mL+ Yen-C 6mL +Malathion 3mL	472	294
Water 300mL+ Malathion 3mL	22	21
	1999/4/14-2000/4/12	
Protein hydrolysates 3mL+ Water 300mL + Malathion 3mL	235	252
Molasses 150mL+ Water 150mL+ Malathion 3mL	45	57
Molasses 150mL+ Water 150mL+ Ethyl acetate 6mL + Malathion 3mL	227	195
Molasses 150mL+ Water 150mL+ Yen-C 6mL - Malathion 3mL	203	179
Water 300mL+ Malathion 3mL	9	11

表十二、含糖蜜與 Ethyl acetate 及番石榴果實之金煌鐘形誘蟲器對果實蠅雌雄成蟲誘引力之比較

Table 12. Comparison of attraction of dome-shape traps contained molasses mixed with ethyl acetate and guava chip to oriental fruit fly tested by rotated wheel method in net house

Attractants	% of total flies attracted	
	♀♀	♂♂
Molasses 50mL＋Water 50mL＋Ethyl acetate 3mL	21.8 ± 8.3a[1)]	26.0 ± 8.6 a
Molasses 50mL＋Water 50mL＋Ethyl acetate 3mL＋DDVP strip	10.4 ± 5.1b	15.1 ± 7.9 b
Guava chip 100g＋DDVP strip	25.3 ± 7.8a	18.4 ± 6.8 b

1) Mean± S.D. derived from 6 trials. Data were transformed to arc sin$\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.

表十三、商品化誘蟲器對果實蠅成蟲誘捕效果之比較

Table 13. Comparison of trapping efficacy of different type traps contained molasses mixed with ethyl acetate to oriental fruit fly tested by rotated wheel method in net house

Trap type	% of total flies attracted	
	♀♀	♂♂
Dome-shape [1)]	20.5 ± 8.7 b[3)]	34.3 ± 9.1 a
Boat-shape [1)]	6.8 ± 3.2 c	5.4 ± 2.4 b
Dome-shape [2)]	42.1 ± 13.5 a	36.7 ± 11.4 a
Boat-shape [2)]	11.3 ± 5.0 c	5.2 ± 6.8 b

1) Attractant was Molasses 50mL+Water 50 mL.

2) Attractant was Molasses 50mL+Water 50mL+Ethyl acetate 3mL.

3) Mean± S.D. derived from 8 trials. Data were transformed to arc sin$\sqrt{x}$ prior to analysis, and means followed by the same letters were not significantly different at 5% level by DMRT.