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研究報告

現行甘藷蟻象 [*Cylas formicarius* (Fabricius)] 防治藥劑之室內藥效評估

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摘要

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本研究目的為檢測現行推薦於甘藷蟻象之 5 種藥劑的防治效力，比較藥劑噴佈法、藷塊浸藥法及藷葉浸藥法處理方式下，藥劑對甘藷蟻象成蟲之致死效果及其殘效性。試驗結果顯示，25% 陶斯松 (chlorpyrifos) 可濕性粉劑、43% 佈飛松 (profenofos) 乳劑及 50% 培丹 (cartap hydrochloride) 水溶性粉劑對成蟲的殺蟲效果較佳，以藷葉浸藥法處理的死亡率於第 3 日可達 100%。此外，除 20% 亞滅培 (acetamiprid) 水溶性粉劑與 20% 達特南 (dinotefuran) 水溶性粒劑以外，殺蟲效果一般隨施用濃度提高而提升。藥劑殘效試驗結果顯示，25% 陶斯松可濕性粉劑以葉片浸藥處理，於處理後第 3 日與第 7 日仍分別保有 100% 與 46% 的殺蟲效果，其餘藥劑於處理後第 3 日的毒殺效果就顯著下降。

關鍵詞：甘藷蟻象、殺蟲劑、防治。

前言

甘藷 [*Ipomoea batatas* (L.) Lam.] 屬旋花科 (Convolvulaceae) 甘藷屬 (*Ipomoea*) 之植物，為世界第七大重要作物，第三大重要根莖類作物 (Chalfant *et al*. 1990; Jansson & Raman 1991)，原產於熱帶之中、南美洲，引入台灣栽培的歷史已有 400 多年，為重要的糧食及工業原料作物 (Lai *et al*. 2008)。

甘藷蟻象 [sweetpotato weevil, *Cylas formicariusformicarius* (Fabricius)] 為鞘翅目 (Coleoptera)，三錐象鼻蟲科 (Brentidae) 之植食性甲蟲，係台灣甘藷生產過程中的關鍵害蟲之一。該害蟲喜好生長於溫熱的環境，分布範圍廣，遍及亞洲、非洲及美洲的熱帶與亞熱帶地區 (Chalfant *et al*. 1990)。旋花科植物為甘藷蟻象的主要寄主，其中包含甘藷與空心菜 (*Ipomoeaaquatica*) 等重要經濟作物 (Sutherland 1986)。甘藷蟻象成蟲平時取食甘藷葉片與莖部為主，於甘藷塊根形成後亦會危害塊根。成蟲卵產於塊根表皮內，幼蟲孵化後直接蛀食塊根，並導致塊根產生萜類物質 (terpenoids)，散發出苦臭味 (俗稱臭香) 而無法食用，造成嚴重的經濟損失 (Sato & Uritani 1981; Chalfant *et al*. 1990; Huang & Cheng 2008)。在台灣，甘藷蟻象平均為害率為 18.1%，嚴重區域甚至高達 74.9%，當中又以食用甘藷的被害率最高 (Yen *et al*. 1982; Huang 1994)。

又台灣的甘藷蟻象 1 年約可發生 7–8 世代，故需要多加管理以控制田間族群數量及避免危害。現行甘藷蟻象防治技術上，仍仰賴化學藥劑為主，並配合性費洛蒙、微生物製劑及耕作防治等技術為輔 (Chang 1966; Su *et al*. 1988; Huang & Cheng 2008)。然而，

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農民常施藥 3–5 次以控制甘藷蟻象為害，因此容易造成過量使用藥劑，導致農藥殘留問題 (Chang 1966; Talekar *et al*. 1985; Huang & Cheng 2008)。早期登記防治甘藷蟻象等地下害蟲的藥劑，多屬系統性且藥效長之藥劑，因此，更加重農產品藥劑殘留之狀況，成為食用及環境安全上的隱憂 (Chalfant *et al*. 1990; Huang 1994)。政府現已將此等農藥禁用，並排除於登記藥劑之列。目前，推薦於防治甘藷蟻象的藥劑僅 2.5% 陶斯松 (chlorpyrifos) 粉劑 1 種 (Plant Protection Manual 2016)，但長期運用同類型藥劑卻又容易使害蟲對藥劑感受性降低，甚至衍生抗藥性的問題 (Chalfant *et al*. 1990; Smith & Hammond 2006)。為此，自 2010 年起，政府陸續以延伸使用方式，新增 20% 亞滅培 (acetamiprid) 水溶性粉劑 50%、培丹 (cartap hydrochloride) 水溶性粉劑、20% 達特南 (dinotefuran) 水溶性粒劑、43% 佈飛松 (profenofos) 乳劑於防治甘藷象鼻蟲類害蟲 (Plant Protection Manual 2016)。

然而，目前無完整試驗揭示延伸使用藥劑對甘藷蟻象之防治效果，因此本研究擬探討登記及延伸使用於甘藷象鼻蟲類之藥劑，比較不同稀釋濃度及施用方式對甘藷蟻象成蟲致死性，並測定藥劑處理後之殘效性，藉此評估藥劑對甘藷蟻象防治效果，提供農民防治選用及藥劑輪替之參考。

材料與方法

供試昆蟲

試驗用甘藷蟻象採集自雲林縣水林鄉田間受危害之甘藷塊根，於室內以「台農 57 號」甘藷塊根累代飼養。飼育室之環境溫度為 25℃ ± 2℃，相對濕度 (RH) 為 60% ± 10%，光暗周期為 12L：12D，飼養期間內皆無接觸農藥或其他化學物品。

供試藥劑

試驗藥劑共 5 種，分別為 20% 亞滅培水溶性粉劑 (億豐農化廠股份有限公司)、50% 培丹水溶性粉劑 (立農化學股份有限公司)、20% 達特南水溶性粒劑 (惠光股份有限公司)、43% 佈飛松乳劑 (台灣先正達股份有限公司) 及 25% 陶斯松可濕性粉劑 (龍燈生物科技股份有限公司)。前 4 者皆為「植物保護手冊」防治甘藷象鼻蟲類之延伸使用藥劑，另因原登記於防治甘藷蟻象之 2.5% 陶斯松粉劑已少有工廠生產，故以較相近之 25% 陶斯松可濕性粉劑取代以進行檢測。試驗藥劑依登記施用濃度 (20% 亞滅培水溶性粉劑為 2,000×、50% 培丹水溶性粉劑為 1,000×、20% 達特南水溶性粒劑為 3,000×、43% 佈飛松乳劑為 1,000×) 及 2×濃度以蒸餾水稀釋為試驗藥液，25% 陶斯松可濕性粉劑則參照登記防治其他害蟲 (紋白蝶及粉介殼蟲類) 之施用濃度 (1,000×)。另以蒸餾水處理作為對照組。

藥劑噴佈試驗

本試驗以藥劑噴佈蟲體之方式檢測殺蟲效果，係以 10 隻甘藷蟻象成蟲為 1 個重複，以二氧化碳迷昏約 5–10 s，並輕置於墊有圓型濾紙 (diam. 9 cm，Whatman® 定性濾紙) 之塑膠培養皿 (diam. 9 cm) 上。利用高壓噴霧塔 (spray tower, Burkard Manufacturing Co., Ltd., UK) 將供試藥液或蒸餾水均勻噴佈於蟲體，每皿噴灑藥量為 3 mL，每處理 5 重複。處理後蟲體移至墊有濾紙的新培養皿中並上蓋，皿內放置「台農 57 號」甘藷圓片 (diam. 3.5 cm，高 0.4–0.5 cm) 供甘藷蟻象取食。裝載甘藷蟻象之培養皿放於恆溫生長箱中，環境溫度為 25℃ ± 2℃，光暗周期為 12L：12D。每 24 h 定期觀察、紀錄甘藷蟻象死亡數量，共觀察 3 d。由於甘藷蟻象具假死習性，為避免誤判死亡數，每次觀察前 5–6 h，預先將甘藷蟻象集中至皿內角落，待觀察時則將該小區內不動或無法正常站立、行走者，及其餘區域無法正常站立、行走者視為死亡。

藷塊、藷葉浸藥試驗

本試驗分別檢測浸藥後甘藷塊根與甘藷葉對甘藷蟻象之取食毒性。試驗用藷塊、葉皆取自「台農 57 號」健康甘藷。藷塊、葉於洗淨後，藷塊切為統一大小之圓形薄片 (diam. 3.5 cm，厚 0.4–0.5 cm)，藷葉則挑選約可完整置入塑膠培養皿 (diam. 9 cm) 者進行試驗。將切片藷

塊、藷葉分別浸泡於 400–450 mL 供試藥液或蒸餾水中，浸泡時間約 10 s，浸泡後則將其放置陰涼處風乾 1–2 h。含藥藷塊放置於墊有濾紙之培養皿內 (規格同上述試驗)，含藥藷葉則以葉背朝上之方式平鋪於內含 1% 瓊脂的培養皿內。每皿各別置入 10 隻甘藷蟻象成蟲並上蓋，每處理為 5 重複。培養皿放於恆溫生長箱中，環境溫度為 25℃ ± 2℃，光暗周期為 12L : 12D。每 24 h 定期觀察、紀錄甘藷蟻象死亡數量，共觀察 3 d。甘藷蟻象死亡數評判按上述方式進行。

殘留毒性試驗

本試驗測定經不同時間處理後之浸藥甘藷葉對甘藷蟻象的殺蟲效果，係將整株甘藷盆栽地上部完全浸泡於供試藥液或蒸餾水中，再放置陰涼處乾燥。待藷葉晾乾 1–2 h (0 d) 或處理 72 h (3 d)、168 h (7 d) 後，將葉片剪下以進行試驗。檢測、觀察方式同上述藷葉浸藥處理流程，每處理 5 重複，每重複檢測 10 隻成蟲。

統計分析

所有累計死亡率數據經角度轉換後，進行雙因子變方分析 (two-way ANOVA)，若處理間具顯著差異，則以最小顯著差異測驗法 (Fisher's least significant difference test; LSD test) 進行比較。Two-way ANOVA 與 LSD test 之顯著水準皆設定為 0.05。試驗數據以 R project (version 3.2.3) 軟體分析。

結果

藥劑噴佈試驗

施藥後 3 d 之不同藥劑處理間，對甘藷蟻象成蟲之致死效果存在顯著差異 (表 1) (Day 1: $F_{4,40} = 55.76$, $P < 0.05$; Day 2: $F_{4,40} = 130.88$, $P < 0.05$; Day 3: $F_{4,40} = 165.59$, $P < 0.05$)，1×、2× 推薦濃度間於 Day 3 具顯著差異 (Day 3: $F_{1,40} = 7.53$, $P < 0.05$)，Day 1 與 Day 2 差異值未達顯著水準 (Day 1: $F_{1,40} = 1.27$, $P = 0.27$; Day 2: $F_{1,40} = 3.03$, $P = 0.09$)。供試藥劑中，以 43% 佈飛松乳劑與 25% 陶斯松可濕性粉劑的殺蟲效果最高，前者 1×推薦濃度即可達 90% 以上之死亡率，後者 2×推薦濃度亦可造成近 100% 死亡率。其餘 3 種藥劑，無論 1× 或 2×推薦濃度皆無顯著殺蟲效果。

表 1. 利用噴佈方式檢測 5 種藥劑對甘藷蟻象成蟲之殺蟲效果。

Table 1. Adulticidal effects of the 5 insecticides against *C. formicarius* by using directed spraying method[z].

Chemical	Conc.[y] (%)	Cumulative mortality (mean ± SD, %)		
		Day 1	Day 2	Day 3
Acetamiprid 20% SP	0.020	42.0 ± 4.47 b[x]	8.0 ± 8.37 c	8.0 ± 10.59 c
	0.010	34.0 ± 8.94 b	10.0 ± 12.25 c	14.0 ± 16.73 c
Cartap hydrochloride 50% SP	0.100	48.0 ± 19.24 b	32.0 ± 21.68 bc	4.0 ± 5.48 c
	0.050	34.0 ± 27.02 b	14.0 ± 13.42 c	2.0 ± 4.47 c
Chlorpyrifos 25% WP	0.050	96.0 ± 5.48 a	98.0 ± 4.47 a	98.0 ± 4.47 a
	0.025	48.0 ± 10.59 b	58.0 ± 4.47 b	62.0 ± 4.47 b
Dinotefuran 20% SG	0.013	8.0 ± 13.04 b	0.0 ± 0.00 c	0.0 ± 0.00 c
	0.007	12.0 ± 8.37 b	2.0 ± 4.47 c	6.0 ± 8.94 c
Profenofos 43% EC	0.086	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
	0.043	86.0 ± 21.91 a	90.0 ± 17.32 a	90.0 ± 17.32 a
Distilled water (control)	-	0.0 ± 0.00	0.0 ± 0.00	0.0 ± 0.00

[z] All data were analyzed using the two-way analysis of variance (ANOVA) and least significant difference (LSD) test, except that of the control group.
[y] The concentration of active ingredient of the five pesticides.
[x] Values within a column followed by the same letter are not significant different at the 5% level of probability.

藷塊、藷葉浸藥試驗

浸藥藷塊之取食試驗結果列如表 2，不同藥劑處理間具顯著差異 (Day 1: $F_{4,40}$ = 78.22, P < 0.05; Day 2: $F_{4,40}$ = 327.33, P < 0.05; Day 3: $F_{4,40}$ = 95.23, P < 0.05)，2 倍推薦濃度與原推薦濃度間之差異亦達顯著水準 (Day 1: $F_{1,40}$ = 29.43, P < 0.05; Day 2: $F_{1,40}$ = 4.22, P < 0.05; Day 3: $F_{1,40}$ = 5.19, P < 0.05)。其中，按 1×與 2×推薦濃度稀釋之 50% 培丹水溶性粉劑、25% 陶斯松可濕性粉劑及 43% 佈飛松乳劑於觀察首日即對甘藷蟻象具顯著致死效果。反之，20% 亞滅培水溶性粉劑與 20% 達特南水溶性粒劑對甘藷蟻象無明顯致死效果，若施用 2× 推薦濃度僅可造成約 20% 之死亡率。

另一方面，若以甘藷葉片浸藥進行檢測 (表 3)，不同藥劑處理間存在顯著差異 (Day 1: $F_{4,40}$ = 74.66, P < 0.05; Day 2: $F_{4,40}$ = 144.65, P < 0.05; Day 3: $F_{4,40}$ = 173.46, P < 0.05)，藥劑濃度提高對甘藷蟻象死亡率則無顯著影響 (Day 1: $F_{1,40}$ = 6.22, P < 0.05; Day 2: $F_{1,40}$ = 0.70, P = 0.41; Day 3: $F_{1,40}$ = 0.94, P = 0.34)。相似於藷塊浸藥處理之試驗結果，無論係 1× 或 2×推薦濃度稀釋之 2 種有機磷劑與 50% 培丹水溶性粉劑，於 Day 3 造成之死亡率皆可達 100%，致死效果顯著高於 20% 亞滅培水溶性粉劑與 20% 達特南水溶性粒劑。

殘留毒性試驗

5 種藥劑殘效試驗之結果如表 4 所示。不同藥劑間效果差異達顯著水準 (Day 1: $F_{5,108}$ = 51.20, P < 0.05; Day 2: $F_{5,108}$ = 63.00, P < 0.05; Day 3: $F_{5,108}$ = 100.13, P < 0.05)，藥劑處理後經不同時間，對甘藷蟻象之致死效果亦具顯著差異 (Day 1: $F_{2,108}$ = 146.21, P < 0.05; Day 2: $F_{2,108}$ = 222.60, P < 0.05; Day 3: $F_{2,108}$ = 250.36, P < 0.05)。藥劑處理後放置 3 d 並接蟲造成的死亡率，僅有未放置處理組之 50% 以下；藥劑處理後放置 7 d 則已無明顯殺蟲效果，與對照組無顯著差異。惟 25% 陶斯松可濕性粉劑處理經 3 d 放置後，仍造成 100% 死亡率；經 7 d 放置後，亦可於成蟲取食之第 3 d 造成 46% 死亡率。

討論

殺蟲劑為防治甘藷蟻象之重要資材 (Waddill 1982; Schalk *et al*. 1991)，然而，甘藷蟻

表 2. 利用甘藷塊浸藥處理方式檢測 5 種藥劑對甘藷蟻象成蟲之殺蟲效果。

Table 2. Adulticidal effects of the 5 insecticides against *C. formicarius* by using sweet potato slice dipping method[z].

Chemical	Conc.[y] (%)	Cumulative mortality (mean ± SD, %) in different days		
		Day 1	Day 2	Day 3
Acetamiprid 20% SP	0.020	14.0 ± 11.40 d[x]	20.0 ± 15.81 b	24.0 ± 18.17 b
	0.010	26.0 ± 26.08 d	16.0 ± 11.40 b	2.0 ± 4.47 b
Cartap hydrochloride 50% SP	0.100	100.0 ± 0.00 a	98.0 ± 4.47 a	96.0 ± 5.48 a
	0.050	82.0 ± 13.04 bc	94.0 ± 5.48 a	76.0 ± 33.62 a
Chlorpyrifos 25% WP	0.050	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
	0.025	70.0 ± 17.32 c	100.0 ± 0.00 a	100.0 ± 0.00 a
Dinotefuran 20% SG	0.013	14.0 ± 11.40 d	16.0 ± 18.17 b	22.0 ± 8.37 b
	0.007	2.0 ± 4.47 d	0.0 ± 0.00 b	6.0 ± 5.48 b
Profenofos 43% EC	0.086	96.0 ± 8.94 ab	100.0 ± 0.00 a	100.0 ± 0.00 a
	0.043	84.0 ± 15.17 bc	100.0 ± 0.00 a	98.0 ± 4.47 a
Distilled water (control)	-	1.0 ± 3.16	1.0 ± 3.16	6.0 ± 5.16

[z] All data were analyzed using the two-way analysis of variance (ANOVA) and least significant difference (LSD) test, except that of the control group.
[y] The concentration of active ingredient of the five pesticides.
[x] Values within a column followed by the same letter are not significant different at the 5% level of probability.

表 3. 利用甘藷葉浸藥處理方式檢測 5 種藥劑對甘藷蟻象成蟲之殺蟲效果。

Table 3. Adulticidal effects of the 5 insecticides against *C. formicarius* by using leaf dipping method[z].

Chemical	Conc.[y] (%)	Cumulative mortality (mean ± SD, %) in different days		
		Day 1	Day 2	Day 3
Acetamiprid 20% SP	0.020	52.0 ± 16.43 cd[x]	54.0 ± 24.08 b	46.0 ± 20.74 b
	0.010	30.0 ± 10.00 d	42.0 ± 8.37 b	40.0 ± 15.81 b
Cartap hydrochloride 50% SP	0.100	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
	0.050	96.0 ± 8.94 a	100.0 ± 0.00 a	100.0 ± 0.00 a
Chlorpyrifos 25% WP	0.050	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
	0.025	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
Dinotefuran 20% SG	0.013	46.0 ± 16.73 cd	42.0 ± 8.37 b	58.0 ± 20.49 b
	0.007	54.0 ± 18.17 cd	48.0 ± 13.04 b	50.0 ± 12.25 b
Profenofos 43% EC	0.086	92.0 ± 8.37 ab	98.0 ± 4.47 a	100.0 ± 0.00 a
	0.043	74.0 ± 19.49 bc	96.0 ± 5.48 a	100.0 ± 0.00 a
Distilled water (control)	-	1.0 ± 3.16	1.0 ± 3.16	3.0 ± 4.83

[z] All data were analyzed using the two-way analysis of variance (ANOVA) and least significant difference (LSD) test, except that of the control group.
[y] The concentration of active ingredient of the five pesticides.
[x] Values within a column followed by the same letter are not significant different at the 5% level of probability.

表 4. 甘藷葉浸藥處理後放置第 0 日、第 3 日及 7 日對甘藷蟻象成蟲之殺蟲效果。

Table 4. Residual effects of five tested insecticides against *C. formicarius* in 0, 3, and 7 days after treatment[z].

Chemical	Conc.[y] (%)	DAT[x]	Cumulative mortality (mean ± SD, %) in different days		
			Day 1	Day 2	Day 3
Acetamiprid 20% SP	0.010	0	50.0 ± 7.07 b[w]	40.0 ± 7.07 bc	42.0 ± 13.04 bc
		3	28.0 ± 17.89 b	12.0 ± 10.95 bc	20.0 ± 10.00 bc
		7	0.0 ± 0.00 b	1.8 ± 4.07 c	3.8 ± 5.24 bc
Cartap hydrochloride 50% SP	0.050	0	96.0 ± 5.48 a	100.0 ± 0.00 a	100.0 ± 0.00 a
		3	34.0 ± 8.94 b	26.0 ± 11.40 bc	36.0 ± 15.17 bc
		7	26.0 ± 23.02 b	14.0 ± 19.49 bc	18.0 ± 21.68 bc
Chlorpyrifos 25% WP	0.025	0	100.0 ± 0.00 a	100.0 ± 0.00 a	100.0 ± 0.00 a
		3	98.0 ± 4.47 a	100.0 ± 0.00 a	100.0 ± 0.00 a
		7	20.0 ± 23.45 b	26.0 ± 27.93 bc	46.0 ± 35.78 b
Dinotefuran 20% SG	0.007	0	38.0 ± 31.14 b	62.0 ± 14.83 b	48.0 ± 16.43 b
		3	12.0 ± 13.04 b	14.0 ± 11.40 bc	20.0 ± 15.81 bc
		7	10.0 ± 10.00 b	12.0 ± 8.37 bc	16.0 ± 20.74 bc
Profenofos 43% EC	0.043	0	82.0 ± 24.90 a	100.0 ± 0.00 a	100.0 ± 0.00 a
		3	4.0 ± 5.48 b	8.0 ± 13.04 c	34.0 ± 11.40 bc
		7	2.0 ± 4.47 b	2.0 ± 4.47 c	2.0 ± 4.47 c
Distilled water (control)	-	0	0.0 ± 0.00 b	0.0 ± 3.16 c	1.0 ± 4.22 c
		3	2.0 ± 4.47 b	2.0 ± 4.47 c	4.0 ± 5.48 bc
		7	0.0 ± 0.00 b	0.0 ± 0.00 c	0.0 ± 0.00 c

[z] All data were analyzed using the two-way analysis of variance (ANOVA) and least significant difference (LSD) test.
[y] The concentration of active ingredient of the five pesticides.
[x] The days after the sweet potato leave treated with pesticides.
[w] Values within a column followed by the same letter are not significant different at the 5% level of probability.

象對於各類藥劑的感受性卻有不小差異 (Mason *et al*. 1991; Setokuchi *et al*. 1991; Smith & Hammond 2006)。有機磷類與氨基甲酸鹽類 (carbamates) 殺蟲劑對甘藷蟻象毒性較高，國內、外多運用作為主要防治藥劑，除陶斯松以外，尚有加保利 (carbaryl)、益滅松 (phosmet) 及甲基巴拉松 (methyl parathion) 等 (Setokuchi *et al*. 1991; Smith & Hammond 2006)。合成除蟲菊酯類 (pyrethroids) 之畢芬寧 (bifenthrin) 及賽扶寧 (cyfluthrin) 亦曾作為美國路易斯安那州 (Louisiana state) 甘藷蟻象等甘藷害蟲的替代防治藥劑，用以減緩甘藷蟻象對有機磷抗藥性之產生 (Smith & Hammond 2006)；此外，百滅寧 (permethrin) 在與甘藷蟻象性費洛蒙混和後，亦對甘藷蟻象具不錯的誘殺效果 (Setokuchi *et al*. 1991)。依據本試驗結果，5 種受測藥劑中，陶斯松與佈飛松，無論直接或間接接觸藥劑之方式，對甘藷蟻象成蟲皆有致死效果 (表 1、表 2、表 3)；沙蠶毒素類似物 (nereistoxin analogues) 的培丹，以藷塊、葉浸藥方式處理，對甘藷蟻象亦具有毒殺效果 (表 2、表 3)；新尼古丁類 (neonicotinoids) 之亞滅培與達特南，按目前登記濃度的殺蟲效果並不理想 (表 1、表 2、表 3)。

為探討不同的藥劑施用方式對甘藷蟻象之殺蟲效果，以作為往後田間應用上的參考，本研究分別以藥劑噴佈法、藷塊浸藥法及藷葉浸藥法 3 種方式進行檢測。相同藥劑種類、濃度下，以藷葉浸藥處理的殺蟲效果最佳，藷塊浸藥法次之，直接噴佈藥劑於蟲體上之殺蟲效果最差 (表 1、表 2、表 3)。然而，此差異於高濃度有機磷殺蟲劑上較不明顯，於 50% 培丹水溶性粉劑與 2 種新尼古丁類藥劑之檢測結果上較易發現該趨勢。本試驗所使用之 5 種藥劑皆具備觸殺與胃毒之作用機制 (MacBean 2012)，結果顯示，藉由取食方式毒殺甘藷蟻象的藷塊、葉浸藥處理所造成之致死效果較高。事實上，若使用的殺蟲劑種類屬於系統性藥劑，則其口服毒性多高於接觸毒性 (Laurino *et al*. 2011; Hsu *et al*. 2012; Pohorecka 2013)。此外，暴露劑量不同亦是影響檢測結果之因子 (Kim *et al*. 2002; Sengonca *et al*. 2006)。噴佈法係將藥劑直接噴附於蟲體，暴露量僅有附著於蟲體上之藥劑，相較之下，藷塊、葉浸藥後所殘留的藥量較多。另由於藷塊較厚，除含藥的藷塊表面，甘藷蟻象仍有機會取食未接觸藥劑的藷塊內部；反之，藷葉極薄，未浸泡藥劑的內部葉肉組織甚少，甘藷蟻象所攝食處多附著有藥劑。是故，藷葉浸泡法所檢測之死亡率普遍較藷塊浸藥法高。此外，關於甘藷蟻象防治之用藥策略，儘管成蟲以甘藷葉片與莖部為食，但因甘藷蟻象常棲息於土壤縫隙內等暗處，一般不以直接噴灑藥劑觸殺成蟲為目的。事實上，不少研究指出，藷苗浸藥處理搭配定期葉面施藥，藉由成蟲間接取食、接觸藥劑的方式，即能達到良好防治效果 (Sherman 1951; Sherman & Mitchell 1953; Sherman & Tamashiro 1954)。

透過本研究之觀察，於 2 種新尼古丁類殺蟲劑與 50% 培丹水溶性粉劑之處理中，原先已產生中毒反應或呈現死亡狀態的部分甘藷蟻象個體，卻於觀察之第 2 日或第 3 日回復正常狀態，而該現象又於藥劑噴佈法之檢定結果最為顯著。因本研究皆於試驗觀察前，預先集中可能為假死狀態的甘藷蟻象，另有對照組作為參考，故可排除、降低假死所造成的誤判。事實上，昆蟲體內具氧化酶 (oxidase)、酯酶 (esterase) 或穀胱甘肽硫基轉移酶 (glutathione S-transferase) 等酵素，可透過不同途徑將殺蟲劑等毒物代謝為低毒或無毒物質，故昆蟲體內代謝酵素於質或量的改變，為提升殺蟲劑抗藥性的方式之一 (Oppenoorth 1965; Ishaaya 1993)。依據往習研究，於銀葉粉蝨 (*Bemisiatabaci*)、家蠅 (*Muscadomestica*)、桃蚜 (*Myzuspersicae*) 及褐飛蝨 (*Nilaparvatalugens*)，皆曾發現蟲體代謝酵素改變而導致新尼古丁類藥劑抗性產生 (Foster *et al*. 2003; Karunker *et al*. 2009; Markussen & Kristensen 2010; Bass *et al*. 2011; Nauen *et al*. 2013)。番茄潛葉蛾 (*Tutaabsoluta*) 與小菜蛾 (*Plutellaxylostella*) 對培丹之抗藥性亦與細胞色素 P450 微粒單體氧化酶 (cytochrome P450 monooxygenase) 等酵素有所關連 (Siqueira *et al*. 2000; Mohan & Gujar 2003)。由此可推測，初期呈

中毒反應之甘藷蟻象，應可利用自身解毒酵素代謝藥劑而得於恢復正常。因此，藥劑噴佈處理下，甘藷蟻象的藥劑暴露量相對較少，酵素易將蟲體內藥劑完全代謝，使回復正常之甘藷蟻象比例較高；反之，部分有機磷類殺蟲劑對甘藷蟻象毒性明顯較高。

試驗中亦發現，甘藷蟻象接觸 20% 亞滅培水溶性粉劑與 20% 達特南水溶性粒劑之新尼古丁類殺蟲劑後，多數在 1 h 內即出現中毒反應，且如上段所述，部分中毒或呈死亡狀態的個體有恢復之現象，故推測該類藥劑對甘藷蟻象應具擊暈 (knockdown) 特性。眾多殺蟲藥劑中，以除蟲菊酯類藥劑的擊暈效果最為明顯，常利用於防治蚊蠅類害蟲 (Burt & Goodchild 1974; Wickham *et al*. 1974)。新尼古丁類藥劑對昆蟲亦有擊暈效果 (Liu *et al*. 1993; Tomizawa *et al*. 1999)。Sfara *et al*. (2005) 曾發現德國蟑螂 (*Blattellagermanica*) 受益達胺 (imidacloprid) 擊暈後，可於一段時間內回復正常，而此現象類似與本研究中甘藷蟻象之狀況。因此，就甘藷蟻象藥劑之毒性檢測與應用，仍應加以考慮擊暈效果存在的可能性，以避免實際田間施用效果不彰之問題。

關於本研究對現行甘藷蟻象防治藥劑之評估，就致死效果、殘效性及作用時間而言，以 2 種有機磷類殺蟲劑與 50% 培丹水溶性粉劑表現為佳，以推薦劑量即可有效壓制害蟲族群；新尼古丁類藥劑之藥效較差，即便提高施用濃度亦無顯著增加殺蟲效果。然而，有機磷劑與培丹皆為廣效性殺蟲劑，對於人、畜及環境等非標的對象皆具毒性，施用上應參照推薦劑量與方式，以減少藥劑造成之危害。就本研究結果可得知，於甘藷蟻象防治藥劑選用上，可以 43% 佈飛松乳劑與 50% 培丹水溶性粉劑為主，2.5% 陶斯松粉劑礙於少有廠商生產，故農友不易取得，或許政府相關單位可研議，將陶斯松其他濃度與劑型之藥劑，延伸推薦使用於甘藷蟻象之防治。因有報告指出，美文松 (mevinphos) 抗性品系之小菜蛾對培丹具交互抗性 (Cheng *et al*. 1984)，僅輪用上述 2 種藥劑尚嫌不足。因此，除施用傳統化學藥劑外，農友亦可搭配耕作防治並施用甘藷蟻象性費洛蒙以大量誘殺雄蟲，藉此減緩抗藥性產生，延續藥劑防治效果。另一方面，印楝油 (neem) 與賜諾殺 (spinosad) 等低毒性藥劑，殺蟲效果亦相當顯著 (Leng & Reddy 2012)，應以此為方向，找尋更多合適、有效且低風險的替代藥劑，增加甘藷蟻象防治藥劑的選項。於未來，亦應進一步檢測藥劑於田間的防治效果，以提供農民更經濟有效的藥劑防治處理方法。

根據本研究結果，部分種類之延伸使用藥劑的室內殺蟲效果不盡理想。依據我國「農藥田間試驗準則」，延伸使用之範圍，乃根據代表性的試驗資料，推估至未經試驗的群組化作物或有害生物類群。按本準則之附表，甘藷或葉用甘藷上的象鼻蟲類推薦藥劑，係以十字花科作物之黃條葉蚤 (*Phyllotretastriolata*) 為代表進行延伸。儘管黃條葉蚤與甘藷蟻象皆屬鞘翅目害蟲，但有時同分類群的生物對藥劑感受性不盡相同 (Stark *et al*. 2009; Khani & Asghari 2012)。因此，往後於藥劑延伸使用上，應再細分有害生物群組或進行田間或室內試驗，以實際瞭解防治效果。如此，更能達到精準用藥，以減少藥劑濫用或浪費，對於農業工作者與消費者亦更有保障。

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Evaluation of Insecticides Recommended for Controlling the Adult of Sweetpotato Weevil [*Cylas formicarius* (Fabricius)] (Coleoptera: Brentidae) in Taiwan

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Abstract

Chen, P. H., T. C. Wang, C. H. Huang, Y. F. Chu, and S. H. Huang. 2017. Evaluation of insecticides recommended for controlling the adult of sweetpotato weevil [*Cylas formicarius* (Fabricius)] (Coleoptera: Brentidae) in Taiwan. J. Taiwan Agric. Res. 66(1):34–43.

The present study was conducted to evaluate the effectiveness of five recommended insecticides for controlling the adult of sweetpotato weevil in Taiwan. Three test methods, tower spray, leaf-dipping and tuber-dipping, were adopted to examine their initial and residual effects on the tested insect in a laboratory conditions. The results revealed that chlorpyrifos (25% WP), profenofos (43% EC) and cartap hydrochloride (50% SP) showed significantly higher effects than the others in all tested methods at the time of treatments, and the mortality of the 3 insecticides was 100% by using leaf-dipping method on the 3rd day. The mortality of the insect increased with the concentration of the insecticides with except of acetamiprid (20% SP) and dinotefuran (20% SG). The residual effects of insecticides to adults showed that the mortality of most insecticidal treatments obtained about only half or less than the initial effects. However, the treatment of chlorpyrifos (25% WP) obtained 100% and 46% mortality at 3 days and 7 days after treatment, respectively.

Key words: Sweetpotato weevil, Insecticide, Control.

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