

殺蟲劑對嘉義地區水稻褐飛蝨 [*Nilaparvata lugens* (Stål)] 與白背飛蝨 [*Sogatella furcifera* (Horváth)] 之室內藥效評估

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摘要

賴柏羽、黃守宏。2021。殺蟲劑對嘉義地區水稻褐飛蝨 [*Nilaparvata lugens* (Stål)] 與白背飛蝨 [*Sogatella furcifera* (Horváth)] 之室內藥效評估。台灣農業研究 70(4):285–297。

本研究利用藥劑噴布法及秧苗浸藥法評估 20 種成品農藥對 2016 年嘉義地區採集之水稻褐飛蝨 [*Nilaparvata lugens* (Stål)] 及白背飛蝨 [*Sogatella furcifera* (Horváth)] 族群 4–5 齡若蟲之致死效果，結果顯示以藥劑噴布法測試對褐飛蝨及白背飛蝨致死率最高之藥劑，分別為 48.34% 丁基加保扶水基乳劑及 16% 可尼丁水溶性粒劑，其致死率分別為 84.7% 及 93.4%，其次為 20% 達特南水溶性粒劑及 20% 免扶克乳劑，致死率介於 69.0–80.3%；以秧苗浸藥法測試對褐飛蝨致死效果，致死率最高之藥劑為 75% 歐殺松水溶性粉劑及 48.34% 丁基加保扶水基乳劑，致死率介於 75.7–91.0%，而對白背飛蝨之致死率較高之藥劑則為 20% 免扶克乳劑、48.34% 丁基加保扶水基乳劑及 25% 派滅淨可濕性粉劑，其處理後白背飛蝨之致死率皆為 84.7%。綜合以上測試結果顯示，僅有 20% 達特南水溶性粒劑、48.34% 丁基加保扶水基乳劑及 20% 免扶克乳劑等 3 種藥劑為同時對褐飛蝨及白背飛蝨具有較佳致死效果之藥劑，因此未來於水稻害蟲防治藥劑選用上，需考量登記藥劑種類外，藉由監測田間飛蝨類族群發生種類並審慎選擇有效藥劑，始能達到經濟有效之防治效果。

關鍵詞：褐飛蝨、白背飛蝨、殺蟲劑、藥劑噴布法、秧苗浸藥法。

前言

褐飛蝨 [*Nilaparvata lugens* (Stål)] 及白背飛蝨 [*Sogatella furcifera* (Horváth)] 為水稻 (*Oryza sativa* L.) 之重要害蟲，同時也具有長距離遷移能力，其危害遍及台灣乃至於整個亞洲水稻栽培地區 (Dyck & Thomas 1979)。此兩種飛蝨於分類上屬於半翅目 (Hemiptera) 蟻蟬亞目 (Fulgoromorpha) 稻蝨科 (Delphacidae) 昆蟲，兩者危害方式相近，常於水稻田混棲發生，並以刺吸式口器通過吸食水稻韌皮部汁液並在植株內產卵危害，影響水稻分蘗及稔實率，嚴重將導致水稻減產，甚至使水稻全株萎凋，形成蝨燒 (hopper burn) 而稻穀無法收成之情形，影響產量至鉅，可造成水稻產量平均 30%

之損失 (Cheng 1976)。此外，褐飛蝨可能做為媒介昆蟲傳播水稻草狀矮化病 (rice grassy stunt virus; RGSV)、皺縮矮化病 (rice ragged stunt virus; RRSV) 及萎凋矮化病毒 (rice wilted stunt virus; RWSV) (Chen & Chiu 1989; Cabauatan *et al.* 2009)；白背飛蝨可媒介南方水稻黑條矮縮病 (southern rice black streaked dwarf virus; SRBSDV) 等病毒病害 (Xu *et al.* 2012)。

台灣每年之褐飛蝨及白背飛蝨族群蟲源主要由海外遷入，褐飛蝨及白背飛蝨於台灣水稻栽培期間發生世代數相似，水稻生育初期即可遷入本田建立族群，歷經 3–4 世代繁衍，族群密度於水稻生育後期達到高峰。過去台灣主要遷入害蟲為褐飛蝨，然而隨遷出地區水稻栽

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培品種改變，特別是在中國華南地區之白背飛蟲族群於近年有逐漸增加趨勢 (Sogawa *et al.* 2003, 2009)，近年台灣監測結果亦發現白背飛蟲遷入數量逐漸攀升 (Cheng & Huang 2004)，水稻發生害蟲相將可能隨之改變。海外遷入之褐飛蟲及白背飛蟲除了直接影響族群密度及水稻受害程度之外，對藥劑之感受性亦受到遷出地區之影響 (Matsumura *et al.* 2008)，特別是主要以藥劑進行防治的地區，將會增加害蟲發生預測與蟲害管理困難度，尤其害蟲產生之抗藥性對遷移性害蟲而言，影響層面更為嚴峻 (Matsumura *et al.* 2009)，因此對遷移性害蟲來自不同遷出地之差異，並定期重新審視現行用藥對遷移性害蟲之感受性變化，為蟲害管理之重要工作。

化學殺蟲劑在台灣仍為農民針對水稻飛蟲類危害之主要防治方法之一，目前台灣登記防治之藥劑種類除早期登記者外，尚包含延伸使用種類，依據政府公告登記於「水稻褐飛蟲」之藥劑共 69 種，依有效成分種類則可分成 32 種，其中氨基甲酸鹽類藥劑占 53%、合成除蟲菊酯類占 16%、新尼古丁類及有機磷類藥劑各占 9%；然而防治白背飛蟲之藥劑係參考登記於「水稻稻蟲類」之藥劑計有 22 種，依有效成分種類則可分成 12 種且皆為延伸使用藥劑 (Plant Protection Manual 2021)，因此農友在白背飛蟲之藥劑選擇上常選擇與褐飛蟲一併防治，然而褐飛蟲用藥中，部分藥劑自 1970 年代登記至今已時間久遠，並自 1977 年後便未針對登記藥劑進行田間篩選試驗 (Cheng & Liu 1978)，使得後來遷入之 2 種飛蟲族群，對於藥劑感受性情形並不明瞭，且登記於褐飛蟲之藥劑雖多，但同時對白背飛蟲亦具效果之藥劑亦需確認，因此本研究藉由檢測現行登記及延伸使用藥劑，且目前於市面上仍有生產販售種類者，針對 2016 年嘉義地區之褐飛蟲及白背飛蟲族群以藥劑噴布法、秧苗浸藥法進行致死率效果評估，期望瞭解該年度遷入之 2 種飛蟲害蟲族群對登記藥劑之感受性差異及變化。

材料與方法

供試蟲源及飼養方式

本試驗使用之褐飛蟲及白背飛蟲試驗蟲源為 2016 年自嘉義縣民雄鄉水稻田 (23°31'37.3"N, 120°26'01.8"E) 採集，於嘉義農業試驗分所溫室中，以感蟲品種水稻植株「台農 67 號」及「台中在來 1 號」作為褐飛蟲及白背飛蟲之飼料水稻，飼養於鋁製生長箱內 (長 92 cm、寬 47 cm、高 81 cm)，經大量飼養後，以繁殖 4 世代以內之蟲源供後續試驗使用。

供試藥劑及配製

本試驗供試之 20 種殺蟲劑成品農藥皆由一般市面上之農藥行購得，試驗使用之藥劑及稀釋倍數為 16.00% 可尼丁 (clothianidin) 水溶性粒劑 (立農化學股份有限公司，台灣雲林縣) 3,000×、25.00% 賽速安 (thiamethoxam) 水溶性粒劑 (台灣先正達股份有限公司，台灣台北市) 10,000×、75.00% 歐殺松 (acephate) 水溶性粉劑 (龍燈生物科技股份有限公司，台灣台北市) 1,500×、10.00% 百滅寧 (permethrin) 乳劑 (龍燈生物科技股份有限公司) 2,000×、20.00% 達特南 (dinotefuran) 水溶性粒劑 (惠光股份有限公司，台灣台南市) 3,000×、20.00% 免扶克 (benfuracarb) 乳劑 (嘉泰企業股份有限公司，台灣桃園市) 500×、20.00% 芬化利 (fenvalerate) 乳劑 (好速化學股份有限公司，台灣新竹市) 3,000×、48.34% 丁基加保扶 (carbosulfan) 水基乳劑 (嘉泰企業股份有限公司) 1,000×、10.00% 依芬寧 (etofenprox) 乳劑 (億豐農化廠股份有限公司，台灣台中市) 750×、50.00% 丁基滅必蟲 (fenobucarb) 乳劑 (日農科技股份有限公司，台灣台南市) 1,000×、9.60% 益達胺 (imidacloprid) 溶液 (台灣拜耳股份有限公司，台灣台北市) 3,000×、50.00% 滅必蟲 (isoprocarb; MIPC) 可濕性粉劑 (日佳農藥股份有限公司，台灣台北市) 5,000×、25.00% 派滅淨 (pymetrozine) 可濕性粉劑 (富農化學工業股份有限公司，台灣桃園市) 1,500×、10.00%

氟尼胺 (flonicamid) 水分散性粒劑 (台灣石原產業股份有限公司, 台灣台北市) 2,000×、40.00% 納乃得 (methomyl) 水溶性粒劑 (台灣杜邦股份有限公司, 台灣台北市) 800×、25.00% 布芬淨 (buprofezin) 可濕性粉劑 (日佳農藥股份有限公司) 1,500×、85.00% 加保利 (carbaryl) 可濕性粉劑 (日農科技股份有限公司) 1,700× 及 50.00% 安丹 (propoxur) 可濕性粉劑 (日佳農藥股份有限公司) 1,000×。另外, 40.00% 丁基加保扶可濕性粉劑 (好速化學股份有限公司) 及 18.20% 益達胺水懸劑 (日農

科技股份有限公司) 係參考登記藥劑中, 相同劑型之有效成分 (active ingredient; AI) 濃度進行配置, 稀釋倍數為 1,067× 及 5,688× (表 1), 依上述不同藥劑之稀釋倍數, 以蒸餾水進行配置。

以藥劑噴布法評估殺蟲劑對褐飛蝨及白背飛蝨之致死效果

取 15 隻褐飛蝨或白背飛蝨 4–5 齡若蟲, 以二氧化碳迷昏約 5–10 s 後, 輕置於墊有圓型濾紙 (直徑 9 cm) 之塑膠培養皿 (直徑 9 cm), 利

表 1. 試驗所用之殺蟲劑類別、濃度、劑型及有效成分濃度。

Table 1. The chemical group, nominal concentration, formulation and active ingredient concentration of the insecticides.

Common name	Chemical group	Nominal concentration	Formulation ^z	Dilution times	AI concentration ^y (mg L ⁻¹)
Acephate	Organophosphate	75.00%	SP	1,500	500.0
Benfuracarb	Carbamate	20.00%	EC	500	400.0
Buprofezin	Chitin biosynthesis inhibitor	25.00%	WP	1,500	166.7
Carbaryl	Carbamate	85.00%	WP	1,700	500.0
Carbosulfan	Carbamate	40.00%	WP	1,067	374.9
Carbosulfan	Carbamate	48.34%	EW	1,000	483.4
Clothianidin	Neonicotinoid	16.00%	SG	3,000	53.3
Dinotefuran	Neonicotinoid	20.00%	SG	3,000	66.7
Etofenprox	Pyrethroid	10.00%	EC	750	133.3
Fenobucarb	Carbamate	50.00%	EC	1,000	500.0
Fenvalerate	Pyrethroid	20.00%	EC	3,000	66.7
Fonicamid	Selective homopteran feeding blockers	10.00%	WG	2,000	50.0
Imidacloprid	Neonicotinoid	9.60%	SL	3,000	32.0
Imidacloprid	Neonicotinoid	18.20%	SC	5,688	32.0
Isoprocarb	Carbamate	50.00%	WP	5,000	500.0
Methomyl	Carbamate	40.00%	SG	800	500.0
Permethrin	Pyrethroid	10.00%	EC	2,000	50.0
Propoxur	Carbamate	50.00%	WP	1,000	500.0
Pymetrozine	Selective homopteran feeding blockers	25.00%	WP	1,500	166.7
Thiamethoxam	Neonicotine	25.00%	SG	10,000	25.0

^z EC: emulsifiable concentrate; EW: emulsion, oil in water; SC: suspension concentrate; SG: water soluble granule; SL: soluble concentrate; SP: water soluble powder; WG: water dispersible granule; WP: wettable powder.

^y AI concentration: The concentration of active ingredient of the insecticides.

用噴藥塔 (Potter spray tower, Burkard Manufacturing Co., Ltd., UK), 以高壓噴霧 (10 lb in^{-2}) 將供試藥液均勻噴布於蟲體, 每皿噴灑藥量為 3 mL, 並以蒸餾水作為對照組, 每處理 3 重複, 處理後蟲體移至供有水稻秧苗之塑膠杯中 (直徑 7 cm、高 12 cm), 分別於 1、2 及 3 d 後觀察並記錄蟲體死亡率。蟲體死亡率評估方式為蟲體腹面朝上並失去反應能力視為死亡 [Insecticide Resistance Action Committee (IRAC) 2012]。

以水稻秧苗浸藥法測試殺蟲劑對褐飛蝨及白背飛蝨之致死效果

將整株水稻秧苗完全浸泡於 400–450 mL 供試藥液或蒸餾水中, 浸泡時間約 10 s, 浸泡植株後置於陰涼處 1–2 h 直至完全晾乾。藥劑處理後之水稻秧苗放入塑膠杯中 (直徑 7 cm、高 12 cm), 再接種入褐飛蝨或白背飛蝨 4–5 齡若蟲, 每重複 15 隻, 每處理 3 重複, 於處理後 1、2 及 3 d 觀察並記錄蟲體死亡率。蟲體死亡率評估方式為蟲體腹面朝上並失去反應能力視為死亡 (IRAC 2012)。

統計分析

試驗所得到之蟲體死亡率, 參考校正死亡率公式 (Abbott 1925) 計算校正後之死亡率, 校正死亡率數據先進行雙因子變方分析 (two-way analysis of variance; two-way ANOVA), 再以最小顯著差異測驗法 (Fisher's least significant difference test; LSD test) 進行比較 ($P < 0.05$)。

結果

以藥劑噴布法評估殺蟲劑對褐飛蝨及白背飛蝨之影響

以藥劑噴布法測試 20 種登記藥劑於登記濃度下對褐飛蝨之致死率, 試驗結果如表 2 所示, 其中以 48.34% 丁基加保扶水基乳劑之處理對褐飛蝨之致死率最高, 於施藥後 3 d, 褐飛蝨死亡率達 84.7%。而 20% 免扶克乳劑、25% 賽速安水溶性粒劑、50% 丁基滅必蝨乳劑、20% 達特南水溶性粒劑及 10% 百滅寧乳劑等 5 種藥劑之處理, 則褐飛蝨於處理 3 d 後, 褐

飛蝨死亡率為 70.7–80.3%, 與 48.34% 丁基加保扶水基乳劑之效果間無顯著差異。其中, 達特南、丁基加保扶及丁基滅必蝨於施藥 1 d 後即有顯著之殺蟲效果, 致死率分別為 81.7%、71.3% 及 73.7%。另外供試藥劑對白背飛蝨之致死率結果如表 3 所示, 16% 可尼丁水溶性粒劑處理後, 白背飛蝨之死亡率相較其他供試藥劑處理為高, 於施藥後 1 d, 白背飛蝨死亡率即高達 88.9%, 3 d 後之死亡率為 93.4%。而 20% 達特南水溶性粒劑、75% 毆殺松水溶性粉劑、25% 派滅淨可濕性粉劑及 20% 免扶克乳劑處理之白背飛蝨, 施藥後 3 d 之死亡率則介於 69.0–80.0%。

以水稻秧苗浸藥法測試殺蟲劑對褐飛蝨及白背飛蝨之影響

將水稻秧苗浸藥後測試不同藥劑對褐飛蝨之致死率, 結果如表 4 所示, 供試藥劑中以 75% 毆殺松水溶性粉劑對蟲體之致死效果最為明顯, 褐飛蝨於接觸浸藥秧苗 3 d 後之死亡率達 91.0%, 致死效果其次為 48.34% 丁基加保扶水基乳劑, 褐飛蝨死亡率為 75.7%, 兩種藥劑所造成之死亡率間無顯著差異。16% 可尼丁水溶性粒劑、20% 免扶克乳劑、50% 安丹可濕性粉劑、25% 派滅淨可濕性粉劑、10% 氟尼胺水分散性粒劑、25% 布芬淨可濕性粉劑及 40% 丁基加保扶可濕性粉劑等藥劑則具 57.7–69.0% 之致死率, 而 10% 百滅寧乳劑僅造成 2.3% 之死亡率。另外測試藥劑對白背飛蝨之致死結果則如表 5 所示, 以 20% 免扶克乳劑、48.34% 丁基加保扶水基乳劑及 25% 派滅淨可濕性粉劑處理之蟲體死亡率最高, 處理後 3 d 後之死亡率皆為 84.7%, 而 20% 芬化利乳劑、25% 賽速安水溶性粒劑、10% 氟尼胺水分散性粒劑及 40% 納乃得水溶性粒劑等處理之蟲體死亡率介於 69.0–76.0%, 上述各藥劑處理間之致死率並無顯著差異。

討論

本研究結果顯示現行登記不同藥劑種類對褐飛蝨及白背飛蝨對之致死率具有相當大的差異, 不論是以藥劑噴布法或水稻秧苗浸藥法進

表 2. 利用藥劑噴布法測試褐飛蟲對登記藥劑之殺蟲效果。

Table 2. Insecticidal effects of the insecticides against *Nilaparivata lugens* by using tower spray method.

Pesticide commodity	Cumulative mortality (mean \pm SD, %) ^z		
	Day 1	Day 2	Day 3
Acephate 75% SP ^y	31.0 \pm 3.5 fg ^x	40.0 \pm 7.0 cd	42.3 \pm 8.1 fgh
Benfuracarb 20% EC	56.0 \pm 10.1 cd	74.0 \pm 20.3 a	80.3 \pm 10.3 ab
Buprofezin 25% WP	0.7 \pm 1.2 h	4.3 \pm 4.0 g	20.0 \pm 3.5 i
Carbaryl 85% WP	0.7 \pm 1.2 h	17.7 \pm 7.5 efg	31.0 \pm 0.0 hi
Carbosulfan 40% WP	2.0 \pm 0.0 h	9.0 \pm 7.0 fg	44.3 \pm 24.1 fgh
Carbosulfan 48.34% EW	71.3 \pm 10.3 ab	76.0 \pm 17.1 a	84.7 \pm 7.5 a
Clothianidin 16% SG	73.0 \pm 11.3 ab	64.3 \pm 15.0 ab	60.0 \pm 11.3 cdef
Dinotefuran 20% SG	81.7 \pm 10.6 a	77.7 \pm 4.0 a	74.0 \pm 0.0 abc
Etofenprox 10% EC	31.3 \pm 7.5 f	45.0 \pm 7.0 bcd	53.7 \pm 8.1 defg
Fenobucarb 50% EC	73.7 \pm 10.0 ab	76.0 \pm 6.0 a	76.0 \pm 6.9 abc
Fenvalerate 20% EC	28.7 \pm 2.5 fg	31.3 \pm 5.0 cde	48.7 \pm 14.6 efg
Flonicamid 10% WG	18.0 \pm 0.0 g	26.7 \pm 4.0 def	49.0 \pm 17.6 efg
Imidacloprid 9.6% SL	32.0 \pm 4.6 ef	36.3 \pm 13.7 cde	48.3 \pm 10.8 efg
Imidacloprid 18.2% SC	22.0 \pm 7.0 fg	50.3 \pm 8.1 bc	53.3 \pm 7.5 defg
Isoprocarb 50% WP	27.7 \pm 1.2 fg	37.0 \pm 10.0 cde	53.0 \pm 6.0 defg
Methomyl 40% SG	44.7 \pm 6.5 de	44.7 \pm 15.0 bcd	49.0 \pm 13.0 efg
Permethrin 10% EC	34.0 \pm 10.0 ef	36.3 \pm 22.3 cde	70.7 \pm 17.0 abcd
Propoxur 50% WP	0.0 \pm 0.0 h	11.3 \pm 4.0 fg	37.7 \pm 6.5 ghi
Pymetrozine 25% WP	57.7 \pm 4.0 cd	48.7 \pm 7.5 bc	64.7 \pm 4.0 bcde
Thiamethoxam 25% SG	64.3 \pm 20.5 bc	60.3 \pm 22.5 ab	78.0 \pm 10.1 abc

^z Mortality rates were corrected with control using Abbott's formula.

^y EC: emulsifiable concentrate; EW: emulsion, oil in water; SC: suspension concentrate; SG: water soluble granule; SL: soluble concentrate; SP: water soluble powder; WG: water dispersible granule; WP: wettable powder.

^x Values in the same column with different letters show significant difference by the least significant difference (LSD) test at 5% level.

行測試，同時對兩種飛蟲皆具良好殺蟲效果之藥劑種類甚少，綜合兩種測試方法對蟲體之致死率結果，20% 達特南水溶性粒劑、48.34% 丁基加保扶水基乳劑及 20% 免扶克乳劑等 3 種藥劑對兩種飛蟲相對具有較佳之致死效果。其中，48.34% 丁基加保扶水基乳劑與有效成分相同之 40% 丁基加保扶可濕性粉劑，對兩種飛蟲及不同方式測試之殺蟲效果卻有顯著落差，因以登記稀釋倍數稀釋後，兩種藥劑之有效成分濃度相差約 1.3 倍所造成，因此在藥劑輪用之基礎上，可優先選擇 48.34% 丁基加保扶水基乳劑進行防治，殺蟲表現較佳。另外，屬於有機磷劑之歐殺松，殺蟲效果雖相對其他殺蟲劑之表現較佳，但由於國人攝取之每日容許攝入量 (acceptable daily intake; ADI) 達到總

量管制 (< 80% ADI) 之因素，藥物毒物試驗所已自 2018 年 8 月將其列為限制登記使用農藥，刪除於水稻使用之範圍。

探討不同藥劑測試方式對褐飛蟲及白背飛蟲之影響，本試驗以藥劑噴布法及秧苗浸藥法進行處理，結果顯示相同藥劑種類及濃度下，多數屬於新尼古丁類之藥劑以噴布法處理之死亡率較秧苗浸藥法處理明顯，其他藥劑則未顯示明顯差異。化學藥劑會受其本身對害蟲之作用特性不同，適合用於藥劑測試之方式亦不同 (Portilla *et al.* 2018), Gerami (2013) 利用不同生物檢測方法，測試棉蚜 (*Aphis gossypii* Glover) 對尼古丁類藥劑之感受性，結果顯示直接將無翅成蟲浸泡益達胺及賽速安藥液處理後，兩種藥劑之半數致死劑量 (lethal dose);

表 3. 利用藥劑噴布法測試白背飛蟲對登記藥劑之殺蟲效果。

Table 3. Insecticidal effects of the insecticides against *Sogatella furcifera* by using tower spray method.

Pesticide commodity	Cumulative mortality (mean \pm SD, %) ^z		
	Day 1	Day 2	Day 3
Acephate 75% SP ^y	68.4 \pm 5.0 b ^x	71.2 \pm 8.2 bc	77.6 \pm 2.7 bc
Benfuracarb 20% EC	53.4 \pm 3.9 bc	60.0 \pm 7.7 cd	69.0 \pm 13.3 bcde
Buprofezin 25% WP	9.0 \pm 3.5 f	28.7 \pm 4.5 ghi	37.7 \pm 4.0 jkl
Carbaryl 85% WP	9.0 \pm 3.5 f	17.7 \pm 13.5 ij	26.3 \pm 11.5 l
Carbosulfan 40% WP	9.0 \pm 3.5 f	13.3 \pm 4.0 j	26.7 \pm 6.5 l
Carbosulfan 48.34% EW	24.0 \pm 8.1 ef	34.9 \pm 7.7 fgh	47.8 \pm 5.1 hij
Clothianidin 16% SG	88.9 \pm 19.2 a	93.4 \pm 3.9 a	93.4 \pm 0.0 a
Dinotefuran 20% SG	68.6 \pm 6.9 b	75.5 \pm 6.7 b	80.0 \pm 4.1 b
Etofenprox 10% EC	20.8 \pm 12.9 ef	25.4 \pm 11.8 hij	30.0 \pm 12.0 kl
Fenobucarb 50% EC	21.4 \pm 14.0 ef	41.1 \pm 10.7 efg	51.8 \pm 8.9 ghi
Fenvalerate 20% EC	11.1 \pm 3.8 f	22.2 \pm 6.7 hij	40.0 \pm 6.7 ijk
Flonicamid 10% WG	44.3 \pm 10.3 cd	62.7 \pm 4.0 bc	64.3 \pm 7.5 def
Imidacloprid 9.6% SL	53.7 \pm 5.7 bc	60.0 \pm 9.6 cd	63.7 \pm 4.7 defg
Imidacloprid 18.2% SC	62.3 \pm 4.5 bc	68.3 \pm 1.2 bc	67.0 \pm 3.6 cde
Isoprocarb 50% WP	31.0 \pm 10.1 de	47.0 \pm 17.1 def	61.3 \pm 8.0 efg
Methomyl 40% SG	7.0 \pm 0.0 f	17.7 \pm 6.5 ij	37.7 \pm 4.0 jkl
Permethrin 10% EC	15.4 \pm 10.4 ef	31.7 \pm 5.1 gh	52.1 \pm 7.0 fgh
Propoxur 50% WP	11.0 \pm 3.5 f	17.7 \pm 0.6 ij	35.7 \pm 10.3 jkl
Pymetrozine 25% WP	24.3 \pm 4.0 ef	62.7 \pm 4.0 bc	73.7 \pm 4.0 bcd
Thiamethoxam 25% SG	44.5 \pm 7.5 cd	49.0 \pm 10.2 de	64.4 \pm 7.7 de

^z Mortality rates were corrected with control using Abbott's formula.

^y EC: emulsifiable concentrate; EW: emulsion, oil in water; SC: suspension concentrate; SG: water soluble granule; SL: soluble concentrate; SP: water soluble powder; WG: water dispersible granule; WP: wettable powder.

^x Values in the same column with different letters show significant difference by the least significant difference (LSD) test at 5% level.

LD₅₀) 皆明顯低於葉片浸藥後再接種棉蚜之處理，由於新尼古丁類藥劑同時具備觸殺及胃毒性 (MacBean 2012)，此類作用於神經系統之藥劑，主要藉由在植物體內系統性移行，使害蟲經口服攝入毒性 (Mullins 1993)，然而對於桃蚜 [*Myzus persicae* (Sulzer)]、柑桔木虱 (*Diaphorina citri* Kuwayama) 等多種半翅目害蟲皆顯示具抗取食性 (antifeeding) 之效果 (Nauen 1995; Nauen *et al.* 1998; Boina *et al.* 2009; Byrne *et al.* 2017)，可能影響藥效表現，因此以藥劑噴布法來測試此類藥劑，較能明顯且快速地評估藥效 (Gerami 2013)。另外，本試驗測試藥劑種類中，部分藥劑有效成分本身無明顯急毒性殺蟲效果，例如已知造成害蟲取食抑制特性

之派滅淨及氟尼胺，以及抑制半翅目幾丁質合成之生長調節劑 (insect growth regulator; IGR) 布芬淨等，分別藉由影響弦音感知器而抑制取食最終導致飢餓死亡，及幾丁質合成受抑制，影響半翅目昆蟲蛻皮而死亡。以局部滴定法 (topical application method) 或藥劑噴布法測試，此 3 類藥劑於短期內結果不太明顯 (Heinrichs *et al.* 1984; Griffiths *et al.* 1991; Tsujimoto *et al.* 2016)，藥劑測試方式常以植體浸藥並延長觀察時間至 5–10 d (Heinrichs *et al.* 1984; Wang *et al.* 2008; IRAC 2012; Matsumura *et al.* 2017)，或計算成蟲接觸藥劑後至下一代數量減少之亞致死效應 (sublethal effect) 進行藥效評估 (IRAC 2012; Roditakis *et al.* 2014;

表 4. 利用水稻秧苗浸藥法測試褐飛蟲對登記藥劑之殺蟲效果。

Table 4. Insecticidal effects of the insecticides against *Nilaparvata lugens* by using rice seedling dipping method.

Pesticide commodity	Cumulative mortality (mean \pm SD, %) ^z		
	Day 1	Day 2	Day 3
Acephate 75% SP ^y	24.3 \pm 6.5 de ^x	75.7 \pm 25.0 a	91.0 \pm 0.0 a
Benfuracarb 20% EC	17.7 \pm 6.5 ef	29.0 \pm 17.1 efg	58.0 \pm 7.0 bcde
Buprofezin 25% WP	42.7 \pm 4.0 bc	55.7 \pm 11.5 abc	64.7 \pm 11.5 bcd
Carbaryl 85% WP	11.0 \pm 0.0 fgh	35.7 \pm 13.5 cdef	51.3 \pm 6.5 cdef
Carbosulfan 40% WP	18.0 \pm 0.0 ef	40.0 \pm 10.1 cdef	57.7 \pm 11.5 bcde
Carbosulfan 48.34% EW	24.0 \pm 0.0 de	71.0 \pm 3.5 a	75.7 \pm 8.1 ab
Clothianidin 16% SG	11.7 \pm 12.0 fgh	42.0 \pm 30.0 bcdef	60.3 \pm 23.6 bcd
Dinotefuran 20% SG	5.0 \pm 5.6 ghi	4.7 \pm 4.0 hi	24.0 \pm 7.0 gh
Etofenprox 10% EC	7.3 \pm 6.4 ghi	31.0 \pm 17.1 defg	48.7 \pm 23.6 def
Fenobucarb 50% EC	24.7 \pm 11.5 de	46.7 \pm 11.5 bcde	53.3 \pm 10.7 cdef
Fenvalerate 20% EC	13.0 \pm 10.1 fg	22.3 \pm 13.6 fghi	39.7 \pm 14.0 efg
Flonicamid 10% WG	53.3 \pm 4.0 a	64.3 \pm 4.0 ab	64.7 \pm 6.5 bcd
Imidacloprid 9.6% SL	0.0 \pm 0.0 i	5.3 \pm 9.2 hi	13.3 \pm 23.1 hi
Imidacloprid 18.2% SC	2.3 \pm 4.0 hi	11.3 \pm 4.0 ghi	13.3 \pm 7.5 hi
Isoprocarb 50% WP	4.0 \pm 0.0 ghi	11.3 \pm 8.1 ghi	46.7 \pm 8.1 def
Methomyl 40% SG	24.0 \pm 0.0 de	38.0 \pm 3.5 cdef	47.0 \pm 3.5 def
Permethrin 10% EC	0.0 \pm 0.0 i	0.0 \pm 0.0 i	2.3 \pm 4.0 i
Propoxur 50% WP	33.3 \pm 4.0 cd	53.3 \pm 7.5 abcd	62.7 \pm 4.0 bcd
Pymetrozine 25% WP	48.7 \pm 8.1 ab	55.7 \pm 13.5 abc	69.0 \pm 7.0 bc
Thiamethoxam 25% SG	9.7 \pm 9.1 fghi	24.7 \pm 23.6 efg	35.3 \pm 15.0 fg

^z Mortality rates were corrected with control using Abbott's formula.

^y EC: emulsifiable concentrate; EW: emulsion, oil in water; SC: suspension concentrate; SG: water soluble granule; SL: soluble concentrate; SP: water soluble powder; WG: water dispersible granule; WP: wettable powder.

^x Values in the same column with different letters show significant difference by the least significant difference (LSD) test at 5% level.

Tsujimoto *et al.* 2016; Matsumura *et al.* 2017), 然而本次結果中卻發現兩種飛蟲以此類藥劑之成品農藥測試時, 3 d 內之死亡率相對於多數藥劑來的高, 可能與成品農藥中除了有效成分外, 另添加其他佐劑成分有關。

根據本試驗褐飛蟲及白背飛蟲對不同藥劑之感受性差異以藥劑噴布處理之結果, 整體而言, 褐飛蟲對氨基甲酸鹽類之藥劑感受性普遍較白背飛蟲高, 而白背飛蟲則是對新尼古丁類藥劑感受性較高, 與 Huang (2013) 檢測 2007–2010 年間台灣西部地區飛蟲族群之結果相似。試驗發現同為新尼古丁類之不同藥劑對褐飛蟲之殺蟲效果之間具明顯差異, 其中益達胺對 2016 年間嘉義地區褐飛蟲族群之殺蟲效果明

顯不佳, 顯示褐飛蟲對益達胺具極高之抗藥性風險 (Chung *et al.* 1982; Nagata *et al.* 2002)。於褐飛蟲主要遷出區, 越南紅河三角洲及中國華中以南之水稻栽培區經過多年大面積選汰, 益達胺抗藥性已逐年攀升, 隨後便發現具有益達胺抗藥性之褐飛蟲族群於台灣及日本等地發生 (Nagata *et al.* 2002; Matsumura *et al.* 2008, 2009), 2006 年間嘉義地區褐飛蟲及白背飛蟲對益達胺之感受性結果顯示, 褐飛蟲對益達胺之 LD₅₀ 為 9.1–18.1 $\mu\text{g g}^{-1}$, 相較於白背飛蟲對益達胺之 LD₅₀ (0.16–0.22 $\mu\text{g g}^{-1}$), 具有較高之容忍性 (Matsumura *et al.* 2008)。2009 年後, 東亞地區白背飛蟲對益達胺、達特南及賽速安感受性仍高 (Matsumura *et al.* 2009;

表 5. 利用水稻秧苗浸藥法測試白背飛蟲對登記藥劑之殺蟲效果。

Table 5. Insecticidal effects of the insecticides against *Sogatella furcifera* by using rice seedling dipping method.

Pesticide commodity	Cumulative mortality (mean \pm SD, %) ^z		
	Day 1	Day 2	Day 3
Acephate 75% SP ^y	35.3 \pm 14.0 cd ^x	46.7 \pm 11.5 efg	66.7 \pm 14.0 bc
Benfuracarb 20% EC	37.7 \pm 18.0 cd	51.0 \pm 25.4 def	84.7 \pm 6.5 a
Buprofezin 25% WP	53.7 \pm 4.0 ab	64.3 \pm 7.5 bcd	66.7 \pm 8.1 bc
Carbaryl 85% WP	2.3 \pm 4.0 g	8.7 \pm 11.5 j	13.3 \pm 10.7 g
Carbosulfan 40% WP	2.3 \pm 4.0 g	11.0 \pm 10.1 j	22.3 \pm 10.3 fg
Carbosulfan 48.34% EW	31.0 \pm 17.6 cde	62.0 \pm 10.1 bcde	84.7 \pm 6.5 a
Clothianidin 16% SG	26.7 \pm 7.5 de	51.3 \pm 14.0 def	62.3 \pm 17.2 bc
Dinotefuran 20% SG	26.7 \pm 7.5 de	55.3 \pm 4.0 cdef	67.0 \pm 10.7 bc
Etofenprox 10% EC	17.7 \pm 13.5 efg	24.3 \pm 14.0 hij	39.7 \pm 14.0 def
Fenobucarb 50% EC	22.0 \pm 3.5 def	53.7 \pm 11.5 cdef	62.3 \pm 19.6 bc
Fenvalerate 20% EC	22.0 \pm 3.5 def	39.7 \pm 11.5 fg	69.0 \pm 10.1 abc
Flonicamid 10% WG	44.7 \pm 15.0 bc	69.0 \pm 3.5 bc	73.7 \pm 4.0 ab
Imidacloprid 9.6% SL	8.0 \pm 2.6 fg	14.3 \pm 4.7 ij	32.7 \pm 4.5 ef
Imidacloprid 18.2% SC	6.7 \pm 0.6 fg	16.7 \pm 1.2 ij	36.0 \pm 4.6 def
Isoprocarb 50% WP	29.0 \pm 10.1 cde	31.0 \pm 7.0 ghi	44.3 \pm 14.0 de
Methomyl 40% SG	60.3 \pm 7.5 ab	75.3 \pm 4.0 ab	76.0 \pm 0.0 ab
Permethrin 10% EC	17.7 \pm 11.5 efg	40.0 \pm 7.0 fgh	53.3 \pm 10.7 cd
Propoxur 50% WP	4.3 \pm 4.0 g	24.7 \pm 7.5 hij	33.7 \pm 10.3 ef
Pymetrozine 25% WP	61.7 \pm 2.9 a	86.7 \pm 3.8 a	84.7 \pm 4.0 a
Thiamethoxam 25% SG	28.7 \pm 8.1 de	57.7 \pm 4.0 cde	69.0 \pm 10.1 abc

^z Mortality rates were corrected with control using Abbott's formula.

^y EC: emulsifiable concentrate; EW: emulsion, oil in water; SC: suspension concentrate; SG: water soluble granule; SL: soluble concentrate; SP: water soluble powder; WG: water dispersible granule; WP: wettable powder.

^x Values in the same column with different letters show significant difference by the least significant difference (LSD) test at 5% level.

Wen *et al.* 2009; Huang 2013), 顯示白背飛蟲尚未對新尼古丁類藥劑產生明顯抗藥性, 值得注意的是, 具益達胺抗性之褐飛蟲對賽速安具交互抗性 (Matsumura *et al.* 2008), 因此在防治上需謹慎選用以防藥效不彰。

本試驗測試氨基甲酸鹽類藥劑結果中, 丁基加保扶及免扶克之殺蟲表現較佳, Yasudomi *et al.* (1994) 以葉部施用免扶克 (500 mg L⁻¹) 對 1980 年日本之褐飛蟲族群具 67% 之死亡率, 與本試驗以 400 mg L⁻¹ 處理之結果 (58.0%) 相似, 而褐飛蟲對丁基加保扶相較於丁基滅必蝨及加保扶較為敏感, 原因可能是尚未發展出明顯之抗藥性 (Wen *et al.* 2009; Min *et al.* 2014)。氨基甲酸鹽類藥劑自 1960 年代應用於水稻害蟲防治至今, 歷史相當悠久, 早期大量

施用下, 1970–1980 年間已有前人指出台灣地區褐飛蟲對加保利、加保扶、納乃得、滅必蝨及安丹等藥劑產生明顯抗藥性 (Ku *et al.* 1976; Chung *et al.* 1982), 1970–2007 年間東亞地區褐飛蟲及白背飛蟲族群對加保利之 LD₅₀ 呈大幅度上升 (Hosoda 1983; Nagata *et al.* 2002; Matsumura *et al.* 2008, 2009), 相比之下, 丁基滅必蝨於 1992 年後整體 LD₅₀ 無明顯上升 (Endo & Tsurumachi 2001; Nagata *et al.* 2002; Matsumura *et al.* 2008, 2009), 但台灣之褐飛蟲族群對丁基滅必蝨之感受性受遷出地區之用藥習慣影響, 而產生相當大之變化 (Matsumura *et al.* 2009; Huang 2013), 另外, 本試驗之結果亦顯示加保利之殺蟲效果最差, 可能與加保利自 1956 年推出至今仍為目前台灣之主流

防治藥劑有關 (Agriculture and Food Agency 2020)。

比較本試驗 3 種合成除蟲菊酯類藥劑對兩種飛蟲之影響，不同藥劑致死效果差異懸殊。以藥劑噴布法測試結果顯示，褐飛蟲對此類藥劑比白背飛蟲略為敏感 (Matsumura *et al.* 2014)，而同一藥劑以秧苗浸藥測試結果大多較噴布法測試差，如百滅寧以藥劑噴布法對褐飛蟲之死亡率 70.7% 相比，以秧苗浸藥法測試死亡率僅有 2.3%，可能由於本次測試之合成除蟲菊酯類藥劑皆不具系統性，僅由秧苗表面接觸之劑量所造成。前人研究顯示，對有機磷類及氨基甲酸鹽藥劑產生抗藥性之褐飛蟲，同時亦對百滅寧具相當高之交互抗性，在芬化利及依芬寧上則未發現明顯升高情形 (Chung *et al.* 1982; Ozaki & Kassai 1984; Matsumura *et al.* 2014)。褐飛蟲對百滅寧與芬化利之感受性差異，可能由於化學結構使解毒機制不同，百滅寧之化學結構上不具 α -氰基，除本身容易氧化降解外，褐飛蟲對百滅寧之代謝途徑類似於馬拉松 (malathion) 及滅必蟲 (MIPC)，透過酯酶 (esterase) 代謝為低毒或無毒物質而容易產生交互抗性 (Chung & Sun 1983; Dai & Sun 1984)。細胞色素 P450 單氧化酶 (cytochrome P450 monooxygenases; CYP) 為褐飛蟲對芬化利具抗藥性之主要原因 (Ling *et al.* 2011)，與不同作用機制藥劑，如益達胺、陶斯松 (chlorpyrifos)、芬普尼 (fipronil)、滅必蟲、布芬淨及沙蠶毒素類 (nereistoxin analogues) 殺蟲劑間則未發現明顯之交互抗性 (Liu *et al.* 2003)，因此田間施用上須考量不同藥劑間之相互影響。

由於水稻褐飛蟲及白背飛蟲之發生生態習性相似，常於田間混合發生，若能選擇同時對兩種飛蟲皆有防治效果之藥劑較為理想，綜合本研究結果，達特南及丁基加保扶為現階段較適合用於同時防治褐飛蟲及白背飛蟲之藥劑，其他多數藥劑則僅對其中一種飛蟲較有效，且對於水稻上之另一危害方式相似之重要害蟲斑飛蟲 [*Laodelphax striatellus* (Fallén)] 之防治效果仍有待評估外，若藥劑選用不當，則可能使其中一種害蟲崛起，造成危害。更甚者，即使選用之成品農藥為防治效果較佳之有效成分，可能因部分藥劑登記稀釋倍數無法達到

有效殺蟲濃度，或施藥方式無法使藥劑附著於褐飛蟲棲息之莖基部處，而造成殺蟲劑量不足 (Cheng & Liu 1978)，害蟲受亞致死效應之激效，從而促進取食及繁殖潛能導致後續危害更為嚴重 (Cheliah & Heinrichs 1980)，長年下來，田間害蟲族群亦會逐漸形成抗藥性問題，最終導致害蟲之再猖獗 (resurgence)。台灣地區之飛蟲類害蟲危害受外來遷移影響非常大，有效的監測藥劑感受性及降低殺蟲劑的選汰壓力為相當重要之工作，於田間若蟲發生時，優先選擇經篩選致死率較高之藥劑或利用不同作用機制殺蟲劑輪用方式，尤其於中南部二期稻作飛蟲類害蟲易發生期間，依照田間害蟲密度監測施用 1-3 次藥劑，並且搭配種植抗蟲品種水稻，水稻收穫後盡速耕犁田間稻樁及再生稻之殘存蟲源、適量的施用氮肥，以及天敵保護，藉以抑制褐飛蟲之族群的增長於經濟危害水平 (抽穗前為 5-10 隻/叢，其後為 20 隻/叢左右) (Cheng 1978) 之下，綜合以上防治方式以達到經濟且有效之防治效果並符合政府推動農藥減量之目標。

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Laboratory Evaluation of the Effect of Insecticides for Controlling Brown Planthopper [*Nilaparvata lugens* (Stål)] and Whitebacked Planthopper [*Sogatella furcifera* (Horváth)] in Chiayi Region

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Lai, P. Y. and S. H. Huang. 2021. Laboratory evaluation of the effect of insecticides for controlling brown planthopper [*Nilaparvata lugens* (Stål)] and whitebacked planthopper [*Sogatella furcifera* (Horváth)] in Chiayi region. *J. Taiwan Agric. Res.* 70(4):285–297.

Abstract

The objective of this study was to evaluate the effectiveness of twenty registered insecticides on 4th–5th instar nymph of brown planthopper [*Nilaparvata lugens* (Stål)] and whitebacked planthopper [*Sogatella furcifera* (Horváth)] collected from Chiayi region during 2016. The mortality of both planthopper species was tested by tower spray and rice seedling dipping methods in laboratory conditions. The results from tower spray tests on brown and whitebacked planthopper indicated that carbosulfan (48.34% EW) and clothianidin (16% SG) were the most effective insecticides, causing the mortality at 84.7% and 93.4% respectively, followed by dinotefuran (20% SG) and benfuracarb (20% EC), mortality between 69.0–80.3%. Acephate (5% SP). Carbosulfan (48.34% EW) exhibited the mortality (75.7–91.0%) significantly higher than others on brown planthopper. Although benfuracarb (20% EC), carbosulfan (48.34% EW) and pymetrozine (25% WP) are commonly recommended for controlling whitebacked planthopper, the mortalities were 84.7% using the rice seedling dipping method. Judging from all results among the twenty insecticides by two test methods, dinotefuran (20% SG), carbosulfan (48.34% EW) and benfuracarb (20% EC) were effective for controlling both brown- and whitebacked planthoppers. To effectively control rice pests, occurrence of planthopper species in the field must be closely monitored. In addition to registered insecticides, efforts are needed to select more effective insecticides in order to achieve cost-effective management.

Key words: *Nilaparvata lugens* (Stål), *Sogatella furcifera* (Horváth), Insecticide, Tower spray method, Rice seedling dipping method.

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