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Research Article

Resistance of *Spodoptera exigua* Population from Nganjuk against Methomyl, Chlorfenapyr, and Emamectin Benzoate

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ABSTRACT

Spodoptera exigua Hubner (Lepidoptera: Noctuidae) is the main pest of shallot causing significant economic losses. The continuous use of insecticides has resulted *S. exigua* to develop resistant against them. This study aims to determine the level of *S. exigua* resistance of Nganjuk and Bantul populations against methomyl, chlorfenapyr, and emamectin benzoate and temporal resistance of *S. exigua* of Nganjuk population to methomyl. Nganjuk population were sampled in June, September, and December. First instar larvae from the first generation were used tested using the leaf-dipping method. Temporal resistance test was carried out using the same concentrations. The resistance ratios of Nganjuk population to the insecticides methomyl, chlorfenapyr, and emamectin benzoate were 58.8; 8.8; and 2.5 fold respectively. The LC_{50} values of *S. exigua* of Nganjuk population collected in June, September, and December were 1127.44; 50.62; and 366.76 mg [AI] liter^{-1}, respectively. The results of this study indicated that the *S. exigua* of Nganjuk population was highly resistant to methomyl and its level has changed over time. Resistance management by rotating the type of insecticide is not sufficient but should also consider its change of resistance pattern over time.

Keywords: insecticide; resistance; *Spodoptera exigua*; temporal

INTRODUCTION

Spodoptera exigua Hubner (Lepidoptera: Noctuidae) is a cosmopolitan and polyphagous insect that feeds on more than 90 plant species belonging to 18 plant families (Greenberg *et al*., 2001). In Brebes, *S. exigua* is the main pest on shallot across different shallot production centers around Indonesia (Triwidodo & Tanjung, 2020). *S. exigua* infestation occurs at both dry and rainy season. In Sulawesi, losses due to *S. exigua* has been estimated to reach 79.65% and in some occasions were able to cause crop failure when no management were done (Rauf, 1999). Larva feed on leaves and leave leaf epidermis that later cause leaves to break and disturb photosynthesis processes (Greenberg *et al*., 2001).

Synthetic insecticides are still the main management option of farmers due to their effectiveness and fast results (Sisay *et al*., 2019). Registered insecticides for *S. exigua* management under the Directorate of Fertilizers and Pesticides, Ministry of Agriculture has increased from 2011 to 2016 from 152 to 250 types (Ministry of Agriculture [*Kementerian Pertanian*], 2016). Several active ingredients are used in Brebes (Central Java), Nganjuk (East Java), and Bantul (Special Region of Yogyakarta) for *S. exigua* management, include chlorfenapyr, chlorpyrifos, methomyl, and emamectin benzoate (Aldini *et al*., 2020). Insecticide application on shallot in Nganjuk can reach 3–4 application per week (Fitriana *et al*., 2020) and 2–3 applications per week in Brebes (Moekasan & Basuki, 2007). Recent research have reported that farmers in Nganjuk and Brebes apply insecticide to manage *S. exigua* on calendar by applying at a 1–3 day interval (Aldini *et al*., 2020). Continuous use of the same synthetic insecticide over time can cause *S. exigua* to develop resistance (Insecticide Resistance Action Committee [IRAC], 2021).

Spodoptera exigua have been reported to develop resis-tance against several insecticides across various countries. In China, *S. exigua* resistances against ema-mectin benzoate and abamectin have been reported and even cross resistances occurred between those two active ingredients (Che *et al*., 2015). *S. exigua* resistances against chlorantraniliprole (Lai *et al*., 2011) and tebufenozide in China (Jia *et al*., 2009). Resistant cases of endosulfan, chlorpyrifos, metho-myl, permethrin, and deltamethrin have been reported in Mexico (Garza-Urbina & Teran-Vargas, 1998). In Pakistan, *S. exigua* have been reported to be medium to high resistant against chlorpyrifos and pyrethroid between 2003 to 2007 and high resistance against deltamethrin between 2004 to 2007 (Ahmad & Arif, 2010). *S. exigua* resistance against insecticides have also been reported in Indonesia against chlorfenapyr, methomyl, and emamectin benzoate in Brebes, Nganjuk, and Bantul (Aldini *et al*., 2021). *S. exigua* resistance is an important challenge for shallot farmers because the increase of management cost. Overapplication and incorrect dose of insecticides application have been reported to reach 33.3% in Nganjuk and 43.3% in Brebes (Aldini *et al*., 2020).

Spodoptera exigua population from Indonesia have been reported to be resistant against certain active ingredients. Populations from Nganjuk and Brebes have been reported to be resistant against methoxyfenozide (Wibisono *et al*., 2007). *S. exigua* were resistant against nine active ingredient, including methomyl (Moekasan & Basuki, 2007). Recent research have reported that *S. exigua* populations from Brebes, Nganjuk, and Bantul have resistant against chlorfenapyr, methomyl, and emamectin benzoate with high resistance against methomyl (Aldini *et al*., 2021). The aim of this study is to monitor resistance levels of *S. exigua* collected from Nganjuk and Bantul against methomyl, chlorfenapyr, and emamectin benzoate, and temporal resistance of *S. exigua* populations from Nganjuk against methomyl. Temporal resistance was only done for methomyl due to *S. exigua* showed the lowest resistance compared to emamectin benzoate and chlorfenapyr. This information will later be used to synthesize strategies for *S. exigua* resistance management.

MATERIALS AND METHODS

Spodoptera exigua Collecting

Spodoptera exigua larvae were collected from March to December 2022. Nganjuk populations were considered resistance while Bantul populations were susceptible (Aldini *et al*., 2021). Sampling in March was done at Sanden, Bantul, Special Region of Yogyakarta. *S. exigua* larvae sampling from Nganjuk, East Java was done at June at Wilangan, September at Bagor, and Desember at Nganjuk. High *S. exigua* infestation (±70%) was an indicator for sampling across Nganjuk. This was done to test temporal resistance of *S. exigua* at high infestation levels. Larvae sampling was done at one location at each district with a total of 250–350 larvae collected at each sampling point.

Spodoptera exigua Mass Rearing

Mass rearing followed methods from Wibisono *et al.* (2007) with modification. Larvae were sampled from various locations and reared at Management Technology Laboratory, Sub Laboratory Pesticide Toxicology, Plant Protection, Faculty of Agriculture, Universitas Gadjah Mada, Yogyakarta. Larvae were reared in 20×20×10 cm plastic containers. Holes were made on plastic containers and sealed with mesh clothes to ensure air circulations. Each containers contained 20–30 larvae with natural fed of 2−3 ≥20-days-old shallot leaf clumps replaced every 1–2 days. Five to six shallot tubers were planted in 40×40 cm polybags. Pupae were moved into imago containers of 30×30×45 cm. Imagoes were fed with 10% honey solution. Shallot plants in 12.5 cm tall and 9 cm diameter plastic containers were used for oviposition locations. One instar from F1 was used for bioassays.

Insecticide

Insecticides used in this research were methomyl (Metindo; 80 active ingredient [AI] liter^{-1}; PT Inti Everspring Indonesia) from group 1A based on its mode of action; chlorfenapyr (Arjuna; 200 gram active ingredient [AI] liter^{-1}; PT Belirang Kalisari, Indonesia) belonging to group 13; and emamectin benzoate (Abenz; 22 gram active ingredient [AI] liter^{-1}; PT Advansia Indotani, Indonesia) belonging to group 6 (Insecticide Resistance Action Committee [IRAC], 2021).

Bioassay

Preliminary testing were done on *S. exigua* populations from Nganjuk and Bantul using methomyl, chorfenapyr, and emamectin benzoate to determine testing concentrations for bioassay with mortality of 5−95% at 96 after insecticide exposure. Preliminary concentration for methomyl was between 3.2×10^{-1} to 3.2×10^{3} mg [AI] liter^{-1}; chlorfenapyr between 3×10^{-1} to 3×10^{3} mg [AI] liter^{-1}; and emamectin benzoate between 2.2×10^{-2} to 2.2×10^{2} mg [AI] liter^{-1}. Highest concentrations used were 10-folds of recommended concentration from each brand. Water was used as solvents and untreated control for bioassays. Testings were done using leaf dipping method (Che *et al.*, 2015). Ten centimeter long shallots leaves were immersed in each treatment and concentration combination for ± 10 seconds and air dried for ± 30 minutes. Leaves were then placed in testing plastic containers with height of 15 cm and diameter of 9 cm. Ten newly emerged first instar larvae were placed in containers with five replications (Wibisono *et al.*, 2007; Yuliani *et al.*, 2020; Aldini *et al.*, 2021). Larva mortality was observed 96 hours after insecticide exposure. Temporal insecticide resistance of *S. exigua* popuilations from Nganjuk against methomyl was done using the same method and concentrations as preliminary studies.

Analysis

The LC_{50} and LC_{95} values were calculated using probit analysis (Finney, 1971) performed in Polo Plus (LeOra Software). The 95% confidence interval was use to determine LC_{50} or LC_{95} significance between groups and significant differences were determined when CI values did not overlap (Macron *et al.*, 1999). Resistance ratio (RR) were calculated by dividing LC_{50} of Nganjuk population with LC_{50} of Bantul population. Temporal resistance of *S. exigua* from Nganjuk population against methomyl was analyzed using similar procedures. Ahmad and Gull (2017) classified RR to six categories, including susceptible RR = 1, very low resistances RR = 2–10, low resistance of RR = 11–20, moderate resistances RR = 21–50, high resistance of RR = 51–100, and very high resistance of RR > 100. Meanwhile, Lai *et al.* (2011) classified RR into six categories consisting of susceptible of RR d” 3, very low resistances of RR = 3–5, low resistance of RR = 5–10, moderate resistance of RR = 10–40, high resistances of RR = 40–160, and very high resistance of RR > 160.

RESULTS AND DISCUSSION

Spodoptera exigua Resistance against Methomyl

Spodoptera exigua populations from Nganjuk had higher resistances against methomyl compared to populations from Bantul. Resistance ratio of Nganjuk was categorized as high resistances of RR = 58.8 folds (Table 1) (Ahmad & Gull, 2017). The LC_{50} of Nganjuk and Bantul populations against methomyl respectively were 1127.44 and 19.16 mg [AI] liter^{-1}, while recommended concentrations was 320 mg [AI] liter^{-1}.

Methomyl was the earliest compound used to manage *S. exigua* compared to chlorfenapyr and emamectin benzoate. Methomyl was first registered in Indonesia in 1987. Methomyl was the most used active ingredients by shallot farmers (Aldini *et al.*, 2020) and has been long used to manage *S. exigua* in Nganjuk with high application frequencies and dosages. The use of methomyl to manage *S. exigua* in Nganjuk reached 56.7% and 76.6% have been used above recommended doses (Aldini *et al.*, 2020). Besides that, shallot was planted 3–4 times in a year in monoculture systems. Methomyl application with high frequencies and for a long time in monoculture systems can cause *S. exigua* resistances to occur faster. Meanwhile, LC_{50} of Bantul population was 16.67% of label recommendations. Resistance differences between Nganjuk and Bantul population may be due to different insecticide use behavior where Bantul farmers have been reported to use methomyl accordingly to label recommendation, less frequently, and rotate between insecticides with different mode of actions (Aldini *et al.*, 2020).

Methomyl is used widely across different countries and *S. exigua* resistances have been reported since the 19th century (Brewer & Trumble, 1994). In Mexico, *S. exigua* were resistant against methomyl with RR between 80–640 folds (Garza-Urbina & Teran-Vargas, 1998). *S. exigua* resistance against methomyl in China were reported at low levels of RR = 3.5–4.5 folds (Su & Sun, 2014). In Indonesia, recent reports of *S. exigua* resistances against methomyl in 2021 occurred in Brebes, Nganjuk, and Bantul with RR=16.5–226.1 folds (Aldini *et al.*, 2021).

Increase of *S. exigua* resistance against methomyl is correlated to increase of detoxification enzyme activity, such as cytochrome P450 monooxygenase or mixed-function oxidase (MFO) (Garza-Urbina & Teran-Vargas, 1998). The same enzyme also works for *S. exigua* against other insecticides. In Japan, *S. exigua* resistances against permethrin was due to increase P450 monooxygenase activity (Shimada *et al.*, 2005). There are several enzyme involved in resistance mechanisms of *S. exigua*. *S. exigua* resistance against indoxacarb in China has been reported due to increase of glutathion S-transferase activity (Gao *et al.*, 2014). Metabolic resistance dose can occur not only due to one enzyme but also several at a time and has been reported in China where *S. exigua* resistance to metaflumizone is caused by increase of esterase, glutathion S-transferase, and cytochrome P450 monooxgenase activity (Tian *et al.*, 2014). This was caused due to the use of several insecticides simultaneously overtime.

Spodoptera exigua Resistance against Chlorfenapyr

Spodoptera exigua from Nganjuk were more resistant to chlorfenapyr than ones from Bantul based on their LC_{50} of 22.33 and 2.54 mg [AI] liter^{-1} while lable recommended concentration of this compound was 300 mg [AI] liter^{-1}. The RR from Nganjuk population was 8.8 fold and categorized as low (Table 1) (Lai *et al.*, 2011). This slight increase should be an indicator to precautious chlorfenapyr use to manage *S. exigua* to not cause resistances.

Chlorfenapyr was registered in Indonesia in 1999 and has been used to manage *S. exigua* in shallot since. The LC_{95} of Nganjuk and Bantul populations were 335 and 262 mg [AI] liter^{-1} respectively, was categorized as low resistance and to be effective against *S. exigua* causing farmers to choose this com by 93.3% of farmers in Nganjuk while only 34.8% of farmers in Bantul (Aldini *et al.*, 2020). However, application frequency and duration of use will also effect *S. exigua* resistance against chlorfenapyr. Chlorfenapyr effectiveness is caused by several factors, such as farmers' rotation among active ingredients, how insecticides are applied, doses used, and application frequency (Glass *et al.*, 1986). As much as 63.3% farmers in Nganjuk and 50% farmers in Bantul rotate between insecticides (Aldini *et al.*, 2020).

Table 1. Nganjuk and Bantul *Spodoptera exigua* population resistances against methomyl, chlorfenapyr, and emamectin benzoate

Regency	District	Insecticide	n	Slope (±SE)	LC_{50} (CI 95%; mg [AI^b] L^{-1})	LC_{95} (CI 95%; g [AI^b] L^{-1})	RR^a		χ^2 (df)
							LC_{50}	LC_{95}	
Nganjuk	Wilangan	Methomyl	250	0.39 (±0.0616)	1127.44 (660.16 – 2608.00) a	79.86 (19.52 – 1115.79) a	58.8	12.1	11.15 (3)
Bantul	Sanden		350	0.65 (±0.1094)	19.16 (0.27 – 114.71) b	6.59 (0.58 – 588.66) a			9.85 (4)
Nganjuk	Wilangan	Chlorfenapyr	350	1.39 (±0.1557)	22.33 (13.49 – 39.15) a	0.34 (0.14 – 1.91) a	8.8	1.3	3.08 (3)
Bantul	Sanden		350	0.82 (±0.1169)	2.54 (0.90 – 5.26) b	0.26 (0.09 – 2.23) a			4.63 (5)
Nganjuk	Wilangan	Emamectin benzoate	350	0.73 (±0.0704)	0.20 (0.11 – 0.35) a	0.04 (0.01 – 0.13) a	2.5	0.4	3.35 (5)
Bantul	Sanden		350	0.52 (±0.0730)	0.08 (0.02 – 0.23) a	0.11 (0.02 – 5.37) a			5.03 (5)

Notes: LC_{50} and LC_{95} value from non significant insecticides were followed by similar letters based on non-overlapping 95% confidence intervals
a = Resistance Ratio (RR) was calculated by dividing LC_{50} and LC_{95} from Nganjuk population with LC_{50} and LC_{95} Bantul population;
b = Active Ingredient.

Chlorfenapyr's wide adoption can reduce its effectiveness against *S. exigua* when application do not follow recommendations. High *S. exigua* resistance against chlorfenapyr with RR=69.3 fold was reported in Wilangan, Nganjuk, while population from other locations were reported with low to moderate (Aldini *et al.*, 2021). The high application frequency and long duration of an active ingredient can cause *S. exigua* resistance against those active ingredients, including chlorfenapyr.

Chlorfenapyr has been adopted in many countries to manage *S. exigua*. From 2009 to 2012, *S. exigua* resistance against chlorfenapyr was low RR=0.4–7 in seven provinces of China (Che *et al.*, 2013) while another study using another population in China had RR value less than 2 from 2011 to 2012 (Zhang *et al.*, 2014). In the Province of Jiangsu no resistance of *S. exigua* against chlorfenapyr was found based on RR=0.9–2.2 kali (Huang *et al.*, 2021) while populations from Shanghai also showed similar results with LC_{50} between 3.49–10.1 mg [AI] liter^{-1} and RR=1–3 fold (Che *et al.*, 2015). Another study from Japan showed no *S. exigua* resistance against chlorfenapyr with RR=0.95 fold (Shimada *et al.*, 2005). A study from Pakistan showed RR=2.2–32 between 1998–2007 (Ahmad *et al.*, 2018) indicating increases of resistance that should be monitored.

Increase of detoxification enzymes have been correlated with *S. exigua* resistances against chlorfenapyr. In Australia, *Helicoverpa armigera* Hubner resistant against chlorfenapyr was due to increase of esterase activity (Gunning *et al.*, 2005). The usage of the same insecticide on Lepidopteran indicate increase of the same enzyme activity. Increase of esterase caused *S. exigua* to develop resistance against metaflumizone (Su & Sun, 2014; Tian *et al.*, 2014). Other studies have shown that multiple enzymes are involved in chlorfenapyr resistances, such cytochrome P450 monooxgenase in *Tetranychus urticae* Koch from Belgia (Van Leeuwen *et al.*, 2005). *S. exigua* resitance against chlorfenapyr is also correlated to esterase, glutathion S-transferase, cytochrome P450 monooxygenease (Tian *et al.*, 2014).

Spodoptera exigua Resistance against Emamectin Benzoate

Emamectin benzoate was still effective against *S. exigua* populations from Nganjuk and Bantul. The LC_{50} value of Nganjuk and Bantul population were 0.20 and 0.08 mg [AI] liter^{-1}) respectively while label recommendation were 22 mg [AI] liter^{-1}. The LC_{50} were 110 and 275 fold lower compared to the recommended concentrations with Nganjuk RR=2.5 fold and categorized as very low resistance (Table 1) (Ahmad & Gull, 2017). That value implied that emamectin benzoate was still effective and can be used as an alternative rotation option.

Emamectin benzoate was first registered in Indonesia in 2001. Emamectin benzoate use in Nganjuk was lower than methomyl and chlorfenapyr to manage *S. exigua* with 26.3% farmers using it compared to 56.7% and 93.3% for methomyl and chlorfenapyr respectively (Aldini *et al.*, 2020). Tests showed that RR of emamectin benzoate was lower compared to methomyl and chlorfenapyr due to its lower use to manage *S. exigua* or only used as a rotational active ingredient. Research showed that rotation was not based solely on rotational programs, but by recommendation from pesticide sellers (23.3%) or other farmers (41.1%) (Aldini *et al.*, 2020). Rotation should be done between different active ingredients to reduce chances of *S. exigua* populations to develop resistance against methomyl, emamectin benzoate, and chlorfenapyr at the same time.

Emamectin benzoate has been used across several countries to manage *S. exigua* and resistance have also been reported. In Shandong, China, *S. exigua* resistance against emamectin benzoate was categorized as very low to moderate (Zhang *et al.*, 2014) while resistance from populations from Jiangsu are categorized as low (Huang *et al.*, 2021). Meanwhile, *S. exigua* resistance against emamectin benzoate from seven provinces di China ranged from very low to very high based on RR=4–348 fold between 2009 to 2012 (Che *et al.*, 2013). In Nanjing, *S. exigua* have been reported to be resistant to emamectin benzoate with RR=1,110 fold and even showed cross resistance to abamectin (202 folds) (Che *et al.*, 2015). Different *S. exigua* resistance against emamectin benzoate was shown from eight locations across China with RR=1.7−104.1 fold (Wang *et al.*, 2018). Management of emamectin resistant *S. exigua* populations requires planning. In Indonesia, recent study reported that *S. exigua* from Nganjuk was resistant against emamectin benzoate with RR= 10.3−46.7 fold and RR=7.2−51.7 fold from Brebes populations, while low resistance of RR=1−6.7 fold was shown from Bantul populations (Aldini *et al.*, 2021).

Several studies has shown biochemical resistant of *S. exigua* against emamectin. Increased mortality after treatment of PBO and DEF syngergist with abamectin application indicated increase of esterase and cytochrome P450 monooxgenase as the mechanism of *S. exigua* resistance against abamectin which has similar mode of action as emamectin benzoate (Ahmad *et al.*, 2018). Cross resistance in insects is commonly reported for different active ingredients with similar mode of action. In China, cross resistance between emamectin benzoate and abamectin against *S. exigua* with high RR of 202 fold indicating that emamectin benzoate resistance is cause by similar detoxification enzymes of abamectin (Che *et al.*, 2015).

Spodoptera exigua **Temporal Resistance against Methomyl**

Temporal resistance of Nganjuk *S. exigua* population against the same concentrations used in the response bioassay showed different responses against methomyl. The LC_{50} of samples taken at June, September, and December were 1127.44 (Table 1); 50.62; and 366.76 mg [AI] liter^{-1} respectively (Table 2).

In general, farmers in Nganjuk plant shallot at similar time and use insecticdie at similar rates and using the same compounds. Insecticide application in Nganjuk used high application frequency with intervals of 1–3 times (Aldini *et al.*, 2020; Fitriana *et al.*, 2020). Methomyl applications in June are done in high intensity due to high *S. exigua* adaptation to methomyl. Methomyl application caused *S. exigua* lower population of susceptible ones causing populations to consist of resistant individuals which later increase pest management cost for farmers. As much as 76.6% farmers in Nganjuk use insecticide doses that exceeded label recommendations (Aldini *et al.*, 2020). Harvest happen in September. Some shallot farmers rotate to emamectin benzoate which may increase susceptibility of *S. exigua* populations against methomyl. This study did not show multiple resistance between methomyl and emamectin benzoate. Insecticide and fungicide applications in December were done in balance frequency

Table 2. Nganjuk *Spodoptera exigua* population temporal resistances against methomyl

Regency	District	Time^a	n	Slope (±SE)	LC_{50} (CI 95%; mg [AI]^c L^{-1})	LC_{95} (CI 95%; g [AI]^c L^{-1})	χ^2 (df)
Nganjuk	Wilangan^b	June	250	0.39 (±0.0616)	1127.44 (660.16 – 2608.00)a	79.86 (19.52 – 1115.79)a	11.15 (3)
Nganjuk	Bagor	September	350	0.78 (±0.0904)	50.62 (26.95 – 89.22)b	6.37 (2.20 – 36.67)a	4.09 (5)
Nganjuk	Kota	December	350	0.78 (±0.1250)	366.78 (197.84 – 709.36)a	46.22 (12.46 – 510.32)a	0.64 (5)

Notes: LC_{50} and LC_{95} value from non significant insecticides were followed by similar letters based on non-overlapping 95% confidence intervals
a = Sampling was done from areas with high *Spodoptera exigua* infestation (>70% plant population were damaged);
b = Data from Wilangan was taken from Table 1 for methomyl;
c = Active Ingredient.

due to high pest and pathogen infestation. Methomyl is still used to manage *S. exigua* because its long history of use by farmers. Less farmers in Nganjuk (36.7%) rotate between active ingredients (Aldini *et al.*, 2020). Rotation was done due to peer recommendation (41.1%), but not to solely rotate (Aldini *et al.*, 2020). Increased methomyl application have caused *S. exigua* resistances. Different response of *S. exigua* against methomyl overtime is caused by farmers methomyl use behavior. Insecticide application methods, doses, frequency, persistence, chemical characteristics, and economic threshold effect insect resistances (Glass *et al.*, 1986).

One factor that determines farmers' pesticide use behavior in Nganjuk is climate. More insecticides are applied more during dry season while fungicides are used more in rainy seasons. Rainfall negatively affect insect population (Chen *et al.*, 2019). *S. exigua* population was shown to be 78 times higher in the dry season compared to rainy season (Rauf, 1999) causing farmers to focus on managing pathogens during the rainy season. The reduce of selection pressure on *S. exigua* using insecticide may reduce its resistance. Sampling were done on June, September, and December that were the dry season, transition between dry and rainy season, and the rainy season. Average rainfall in the District of Tanjunganom, Regency of Nganjuk from 2015–2021 in June, September, and December were 28.57; 58.71; and 257.14 mm (*Badan Pusat Statistik* [BPS], 2023).

Monitoring of *S. exigua* resistance against insecticides is important to determine insecticide effectiveness over time and to inform effective insecticide rotations over time. This step can hopefully contribute to insecticide resistance management.

CONCLUSION

S. exigua populations from Nganjuk were resistance against methomyl, chlorfenapyr, and emamectin benzoate with RR of 58.8; 8.8; and 2.5 folds respectively. *S. exigua* resistance against methomyl in Nganjuk varied from each season (June, Septem-ber, and December 2022) with LC_{50} of 1127.44; 50.62; and 366.76 mg [AI] $liter^{-1}$ respectively.

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