J. Fac. Agr., Kyushu Univ., **62** (2), 439–443 (2017)

Efficacy of the Extract from Pongam Leaves (*Pongamia pinnata* L.) Against *Spodoptera exigua* (Hübner) and *Spodoptera litura* Fabricius (Lepidoptera: Noctuidae)

Dang Hoa TRAN[1], Masami TAKAGI[2] and Takatoshi UENO[2]*

Laboratory of Insect Natural Enemies, Division of Biological Control, Department of Applied Genetics and Pest Management, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan
(*Received April 30, 2017 and accepted May 10, 2017*)

The beet armyworm *Spodoptera exigua* (Hübner) and the tobacco armyworm *S. litura* Fabricius (Lepidoptera: Noctuidae) are economically important insect pests of a variety of crops primarily in tropical and subtropical regions. Conventional control of these pests usually depends on synthetic chemical insecticides. Botanical pesticides have recently been paid considerable attention as an environmentally friendly measure to manage various insect pests. The present study was carried out to determine the efficacy of a leaf extract from pongam tree *Progamia pinnata* L. against the two armyworms. The results showed that the acute lethal toxicity of pongam leaf extract was high against the two armyworm species; the LC_{50} values were 1.94%, 1.52% and 1.10% at 24, 48 and 72 hours, respectively for *S. litura* whereas the values for *S. exigua* larvae were 3.18%, 2.57% and 1.89% at 24, 48 and 72 hours, respectively. Our study also indicated that low concentrations of pongam leaf extract caused significant reductions of vitality of the armyworms; they took more time to mature during the larval stage. Taken together, the treatment with a pongam leaf extract can negatively affect the armyworm populations directly and indirectly, and cause a reduction of overall pest numbers in the next generation. Thus, the pongam leaf extract is a recommendable bio–pesticide to control the armyworms.

Key words: herbal pesticide, sub–lethal toxicity, integrated pest management, chemical control

INTRODUCTION

The beet armyworm *Spodoptera exigua* (Hübner) and the tobacco armyworm *S. litura* Fabricius (Lepidoptera: Noctuidae) are economically important polyphagous insect pests of various crops, in particular, in tropical and subtropical regions (Brown and Dewhurt, 1975). Conventional control of these pests is dependent on synthetic chemical insecticides. However, excessive reliance on insecticides can cause environmental pollution and development of pesticide resistance while it should have strong negative impacts on non–target organisms including natural enemies that are beneficial to crop production (van Driesche and Bellows, 1996; Tran *et al*., 2004; Tran and Ueno, 2012). In Vietnam, the two armyworms are also serious pests of various crops but armyworm control with synthetic insecticides does not always work well (Ueno, 2006; 2015). Thus, alternative measures that are costly reasonable are on demand in the country.

Plants commonly produce chemical compounds to protect themselves from herbivores like insects. There are considerable evidence that materials or extracts from several plant species are useful as botanical or organic pesticides (for review; Prakash and Rao, 1996). Botanical pesticides are potentially an alternative to conventional synthetic pesticides, because it is usually believed that the natural products would have lesser negative impacts on environments and human health (Isman *et al*., 2011) while botanical pesticides are reasonably costly and may be effective to control target pests; in fact, a number of medicinal plants have been used as pest control materials (Lale, 1992; Isman, 1995; Pavela, 2009; Roy *et al*., 2010; Erler *et al*., 2010).

Pongam *Progamia pinnata* L. is a forest tree that belongs to the family Leguminosae and has widely been used for biodiesel production (Krishnamurthi, 1969; Meera *et al*., 2003). It is widely distributed throughout tropical Asia including South East Asia and India as far as the Seychelles islands and Australia (Arote and Yeole, 2010). Pongam has long been used as crude drugs to treat wounds, painful rheumatic joints, skin disease, abscesses, tumor, ulcers, diarrhea, and so on (Shoba and Thomas, 2001; Meera *et al*., 2003). In addition, pongam has widely been tested for their insecticidal, nematicidal, antifungal, antibacterial and antiviral activities (Simin *et al*., 2002; Kerasi *et al*., 2010).

More recently, pongam has been recognized as a botanical pesticide; several studies have confirmed the pesticidal properties against insect pests (Samuel *et al*., 2009; Yankanchi and Lendi, 2009; Mamun *et al*., 2009; Lale and Kulkarni, 2010; Verma *et al*., 2011). For example, toxicity of pongam is shown for the human head louse *Pediculus humanus capitis* (Samuel *et al*., 2009), the bean beetle *Callosobruchus chinensis* (Yankanchi and Lendi, 2009), the termite *Odototermes obesus* (Verma *et al*., 2011), and the red flour beetle *Tribolium castaneum* (Mamum *et al*., 2009). Also, a deterrence or repellent effect has been demonstrated against mosqui-

[1] Department of Plant Protection, Faculty of Agronomy, College of Agriculture and Forestry– Hue University, Hue City, Vietnam
[2] Laboratory of Insect Natural Enemies, Division of Biological Control, Department of Applied Genetics and Pest Management, Faculty of Agriculture, Kyushu University, Fukuoka 812–8581, Japan
* Corresponding author (E–mail: ueno@grt.kyushu–u.ac.jp)

toes (Lale and Kulkarni, 2010).

The previous studies, however, have focused on toxic activity of materials prepared from pongam seeds, stems and roots whereas only a few reports have been addressed pesticidal effects of the extract from pongam leaves (Tran *et al*., 2016). However, pongam leaves are an abundantly available raw material, and, if the leaves are usable for pest control, manufacturing botanical pesticides in large quantities is possible by using pongam leaves. We have previously demonstrated that pongam leaf extracts are usable to control the turnip aphid (Tran *et al*., 2016). Accordingly, in the present study, we focus on a methanol extract from pongam leaves and examine its potential to control the beet armyworm and the tobacco armyworm. We will show the efficacy of armyworm control with a pongam leaf extract and discuss the usefulness of pongam as a botanical pesticide.

MATERIALS AND METHODS

Insect rearing

Seeds of pak choi *Brassica chinensis* were sown in a tray ($20\,cm \times 60\,cm \times 15\,cm$) in a mixture soil (40% water content, pH=5.5–6.5, 0.035%N, 0.123%P_2O_5, 0.018%K_2O). Two weeks after germination, each seedling plant was transplanted to a plastic pot ($9\,cm$ in diameter). Leaves from grown plants were used for feeding the armyworms.

Larvae of *S. exigua* and *S. litura* were collected from severely infested plants grown at the experimental farm of Hue University, Vietnam. Both insects were reared individually in plastic boxes ($10\,cm \times 5\,cm \times 5\,cm$) and reared on pak choi leaves. The boxes were maintained in an environmental chamber at a constant temperature of 25ºC under a photoperiod of 16L: 8D until the larvae pupated. Sterilized soil was provided for pupation. The pupae were collected from the soil and were placed in a shelf ($200\,cm \times 60\,cm \times 50\,cm$) covered with a fine nylon mesh. The self was maintained at the same condition mentioned above and was used for rearing the adult moths for oviposition. Potted pak choi plants were placed inside the shelf to obtain eggs of the moths. Plants were removed from the shelf to collect newly hatching larvae, and larvae were reared on pak choi leaves.

Preparation of plant extracts

We collected the leaves of *P. pinnata* from Phu Vang District, Thua Thien Hue Province, Vietnam. The pongam leaves were washed under tap water to remove dirt and debris. The leaves were kept in shade for air–drying and then were dried in the oven at 60ºC to gain constant weight. The leaves were then powdered with an electric grinder. The powdered leaves were packed in Soxhlet apparatus. Upon use, the pongam leaf powder was used to extract with methanol. The extract was concentrated in a vacuum evaporator. The extract was then stored at 4ºC in amber colored airtight bottles. Different concentrations of the plant extract were prepared by dissolving the stock solution in Acetone 300, 99.5+% (GC) before the bioassays mentioned below.

Bioassays

Bioassays were done as follows. The diluted extract was evenly applied on pak choi leaves (approximately $5\,ml$ per potted plant) with a power–pack aerosol hand sprayer (Hand Spray Nozzle, Takeda Engei Co., Japan). No surfactants were added to the extract. Two hours after spraying, 5 freshly hatched first instars (6 hours old) of *S. litura* or *S. exigua* each were gently transferred on a potted plant (10–15 cm in height with 2–3 leaves). Then, the potted plant was put in a plastic cage ($45\,cm \times 30\,cm \times 25\,cm$) covered with a fine nylon mesh. As a control, distilled Acetone was applied to pak choi plants, and then test armyworms were placed on them in the same way as mentioned above. The cages were kept at 25ºC, 60–70% humidity under a 16L: 8D light period.

First, the approximate LC_{50} was determined using the two armyworm species. The stock solution was diluted with Acetone 300, 99.5+% (GC) to prepare a 5% solution. The concentrations of test solutions were adjusted by adding acetone to the 5% solution. The doses tested were from 0.0 to 3% for both *S. exigua* and *S. litura*. The mortality was determined at 24 h after spraying. Test with a given concentration was conducted with one potted plant with 15 first instars. For each concentration, tests were replicated three times; thus, 45 armyworms were in all used for each concentration.

Second, sublethal effects on armyworms were examined. For this purpose, we examined the development (measured as time in days) of the armyworms treated with low concentrations of the extract. A serial time–dose response bioassay was used to determine response of the insects to different doses lower than LC_{50} values. The ranges of doses were prepared by diluting the extract with acetone; doses equivalent to 0.5, 1.0 and 1.5% were tested. Mortality was determined for each larval instar. Alive insects were maintained under the above conditions, and were monitored daily until all insects had pupated.

Data analyses

Statistical treatments were carried out with the aid of JMP 11.2 (SAS, 2014). Probit analysis was used to determine LC_{50} and LC_{95} values. The development time was analyzed with one–way ANOVA, and the means were separated by Fisher's PLSD tests.

THE RESULTS

Results of the probit analysis of dose–response data (LC_{50}, slopes and intercepts of the dosage–mortality lines) for *S. exigua* and *S. litura* are summarized in Table 1. The pongam leaf extract was toxic to *S. litura* with the LC_{50} found to be 1.934%, 1.517% and 1.097% at 24, 48 and 72 hours, respectively. The LC_{95} was 4.431%, 3.465% and 2.473% at 24, 48 and 72 hours, respectively. Against *S. exigua*, the LC_{50} of the pongam leaf extract

Table 1. Median and 95% lethal concentrations of pongam leaf extract to *Spodoptera litur*a and *S. exigua*

Time after treatment (hours)	LC_{50} (%)	95% fiducial limits of LC_{50}	LC_{95} (%)	Regression equation ($Y=a+bx$)	x^2 (df, P)	R^2
Spodoptera litura						
24	1.943	1.714 – 2.207	4.431	Y = – 1.284+0.661 X	20.120 (19, 0.387)	0.837
48	1.517	1.327 – 1.705	3.465	Y = –1.281+0.844 X	21.453 (19, 0.312)	0.884
72	1.097	0.940 – 1.244	2.473	Y = –1.312+1.195 X	24.485 (19, 0.178)	0.893
Spodoptera exigua						
24	3.175	2.688 – 4.101	6.778	Y = – 1.450+0.457 X	12.153 (19, 0.879)	0.728
48	2.574	2.172 – 3.261	6.487	Y = – 1.082+0.420 X	14.513 (19, 0.753)	0.716
72	1.891	1.563 – 2.305	5.639	Y = – 0.830+0.439 X	12.504 (19, 0.863)	0.755

Table 2. Effects of different doses of pongram leaf extract lower than LC_{50} on developmental time in days of *Spodoptera litura* and *S. exigua*

Concentration (%)	*Spodoptera litura*		*Spodoptera exigua*	
	Larva	Pupa	Larva	Pupa
0.0	22.4±0.36a	7.8±0.14a	13.8±0.07a	7.9±0.19a
0.5	24.0±0.52ab	8.0±0.30a	14.9±0.05b	8.4±0.31a
1.0	24.0±1.18ab	8.7±0.33a	15.3±0.13b	8.1±0.46a
1.5	26.3±1.93b	8.3±0.33a	16.0±0.21c	8.3±0.49a
df	67	59	115	68
F–value	4.64	2.09	79.61	0.69
P–value	0.005	0.112	<0.0001	0.601

Means with the same letters within a column are not significantly different by Fisher's PLSD after one–way ANOVA (α =0.05). Data are shown as mean±SE.

was found to be 3.175%, 2.574% and 1.891% at 24, 48 and 72 hours, respectively. The LC_{95} was 6.778%, 6.487% and 5.639% at 24, 48 and 72 hours, respectively.

When the first instars of *S. litura* were exposed to extracts with different concentrations lower than LC_{50}, the mean total larval developmental times were 24.0, 24.0 and 26.3 days at concentration of 0.5, 1.0 and 1.5%, respectively, and the values were larger than that of control (acetone) (22.4 days) (F=4.637; df=67; P<0.01). There was a clear trend that the larval developmental time increased with increasing doses (Table 2). There was no significant difference among the mean developmental times of the pupae (P>0.05) (Table 2).

Development time of *S. exigua* exposed to extracts lower than LC_{50} is summarized in Table 2. The total larval development time increased significantly as the extract concentration increased (F=79.607; df=115; P<0.0001). The mean developmental times in day of total larval stages were 14.9, 15.3 and 16.0 at concentration of 0.5, 1.0 and 1.5%, respectively, the values of which were larger than that of control (13.8 days). There was no significant difference in the mean developmental times of the pupae (P>0.05), suggesting that the extract did not affect pupal development.

DISCUSSION

The present experiments have shown that the extract of pongam leaves has sufficiet larvicidial activity against the beet armyworm and the tobacco armyworm. Insecticidal properties of pongam leaf extracts can be attributed to karanjin (3–methoxy furano–2,3,7,8–flavone) and pongapin (2–(1,3–Benzodioxol–5–yl)–3–methoxy–4H–furo[2,3–h]–1–benzopyran–4–one), and these are the major flavonoids in pongam (Asolkar *et al*., 1992; Katekhaye *et al*., 2012). Each of karanjin and pongapin has been shown to possess pesticidal properties (Kumar *et al*., 2006, Verma *et al*., 2011). Because pongam contains both flavonoids, there may be a significant synergistic effect that enhances the toxicity of pongam (Poonia and Kaushik, 2013). In fact, the present study showed that the two armyworms were highly susceptible to pongam leaf extract, and its LC_{50} values were low (Table 1). Thus, the acute lethal toxicity of pongam leaf extract is sufficiently high usable for the control of the two armyworms.

The leaf extract of pongam tree was also reported to be effective against some insect pests (Sridhar and Chetty, 1989; Kulat *et al*., 1997; Samuel *et al*., 2009;

Tran *et al*., 2016). Samuel *et al*. (2009) demonstrated that a methanol extract of pongam leaves showed excellent anti–lice activity with values ranging between 32.6 and 82.9%. Similarly, high toxicity of pongam leaf extract has also been reported for the second instars of *S. litura* (LC_{50} 72h: 5.44%), the larvae of *Trogoderma granarium* (LC_{50} 72h: 19.9 μ/insect) and the adult of *T. granarium* (LC_{50} 72h: 65.9 μ/insect) (Kumar *et al*., 2006).

The extracts of pongam bark, leaf and seed oil have antifeedant and/or repellent effects on insect pests. For example, Kumar *et al*. (2006) showed an antifeedant effect of the extracts on *S. litura* and repellent effects on stored product pests *Trogoderma granarium* and *Tribolium castaneum*. Likewise, a repellent effect was confirmed for blood sucking mosquitos (Lale and Kulkarni, 2010). Although we did not examine the presence of antifeedant effect on the two armyworms, our study did provide evidence that low concentrations of a pongam leaf extract caused a significant increase in larval developmental time of the two armyworms (Table 2). The longer developmental time detected in our study may result from an antifeedant function of the pongam leaf extract. Alternatively, physiologically sublethal effects may be present on the extract, which can result in slowed growth rate of the armyworms.

Sub–lethal effects are often chronic and are expressed as some change in the insect's life history attributes. Consequently, such effects may have a long–term impact on the reproduction over generations or on the population level. Sub–lethal residues can negatively affect insects that survive pesticide applications, e.g., those that emerge as adult from protected situations, or those that disperse into areas where residues exist. Biological parameters to detect such sublethal effects include daily fecundity, total progeny production, longevity, developmental time, egg viability, consumption rates and insect behavior (Ruberson *et al*., 1998).

In addition, the indirect negative effects of plant extracts on insect pests expressed as deterrents and repellents may have potentially important behavioral consequences that further reduce pest severity. More than six decades ago when the use of chemical pesticides was not common, farmers used different part of pongam to protect paddy crop in India (Lale and Kulkarni, 2010). The presence of pongam tree near paddy field helped in repelling harmful insects. Also, dried leaves of *P. pinnata* are used as an insect repellent in stored grains. Recently, the repellent effect of pongam on mosquito was also reported (Lale and Kulkarni, 2010).

Available literatures have suggested that natural extracts from plants should be noticed for its safety for the environment and human health while the emergence of resistance is minimal due to its different mode of action (Isman, 1995; Breuer *et al*., 2003). Moreover, some extracts (containing similar substances to those present also in *P. pinnata* leaves) may attract natural enemies and thus increase natural parasitization levels (Charleston *et al*., 2006). Botanical insecticides based on pongam leaves thus seem to possess the potential for being used together with biological control agents (Tabone *et al*., 2010). Therefore, a trial is recommended to test pongam leaf extracts for the armyworm management.

Although the toxicity of *P. pinnata* to the beet armyworm and the tobacco armyworm has been confirmed under a laboratory condition in the present study, the efficacy as a crop protectant should also be assessed under the field condition. The recent field trials of the other botanical insecticides to control pest insects and mites have demonstrated that botanical insecticides can be as effective as conventional insecticides and are compatible with conventional products (Dadang *et al*., 2009; Erler *et al*., 2010). These studies suggest that the botanical pesticides are usable as a stand–alone product in certain pest/crop contexts, but may be even more effective as a tank mix with conventional insecticides (Isman *et al*., 2011). Also, it is not examined whether the effects of such botanical insecticides on target pests are due to the contact toxicity, or residual toxicity or deterrence (i.e., sublethal behavioral effects). Further laboratory, greenhouse and field experiments with *P. pinnata* are needed to address this question.

AUTHOR CONTRIBUTIONS

D. H. Tran designed and conducted the laboratory experiments, analyzed the data, and prepared the first draft of the manuscript. M. Takagi contributed in molding the research concept. T. Ueno discussed the results and polished up the manuscript.

ACKNOWLEDMENTS

This research is funded by Vietnam National Foundation for Science and Technology Development (NAFOSTED) under the grant number 106.11– 2012.88.

REFERENCES

Arote, S. R. and P. G. Yeole 2010 *Pongamia pinnata* L.: A comprehensive review. *Int. J. Pharm. Tech. Res*., **2**: 2283–2290

Asolkar, L. V., K. K. Kakkar and O. J. Charkre 1992 *Glossary of Indian Medicinal Plants with Active Principles*. Part I (1965–1981). CSIR, New Delhi, India

Breuer, M., B. Hoste, A. De Loof and S. N. H. Naqvi 2003 Effect of *Melia azedarach* extract on the activity of NADPH–cytochrome c reductase and cholinesterase in insects. *Pestic. Biochem. Physiol*., **76**: 99–103

Brown, E. S. and C. F. Dewhurst 1975 The genus *Spodopteta* (Lepidoptera, Noctuidae) in Africa and the Near East. *Bull. Entomol. Res*., **65**: 221–262

Charleston, D. S., R. Kfir, M. Dicke and L. E. M. Vet 2005 Impact of botanical pesticide derived from *Melia azedarach* and *Azadirachta indica* on the biology of two parasitoid species of the diamondback moth. *Biol. Cont*., **33**: 131–142

Dadang, E., D. Fitriasari and D. Prijono 2009 Effectiveness of two botanical insecticide formulations to two major cabbage insect pests on field application. *J. ISSAAS*, **15**: 42–51

Erler F., H. Cetin, H. Saribasak and A. Serttas 2010 Laboratory and field evaluations of some botanical pesticides against the cedar leaf moth *Acleris undulana*. *J. Pest Sci*., **83**: 265–272

Isman, M. B. 1995 Leads and projects for the development of

new botanical insecticides. *Rev. Pestic. Toxicol*., **3**: 1–20

Isman M. B., S. Miresmailli and C. Machial 2011 Commercial opportunities for pesticides based on plant essential oil in agriculture, industry and consumer products. *Phytochem. Rev*., **10**: 197–204

Katekhaye, S., M. S. Kale and K. S. Landdha 2012 Development and validation of an HPLC method for karanjin in *Pongamia pinnata* Linn. leaves. *Indian J. Pharm. Sci*., **74**: 72–75

Kesari, V., A. Das and L. Rangan 2010 Physico–chemical characterization and antimicrobial activity from seed oil of *Pongamia pinnata*, a potential biofuel crop. *Biomass Bioener*., **34**: 108–115

Krishnamurthi, A. 1969 *The Wealth of India. vol. VIII*. Publication and Information Directorate. CSIR, New Delhi, India

Kulat, S. S., S. A. Nimbalkar and B. J. Hiwase 1997 Relative efficacy of some plant extracts against *Aphis gossypii* (Glover) and *Amrasca devastans* (Distant) on okra. *PKV Res. J*., **21**: 146–148

Kumar, V., K. Chandrashekar and O. P. Sidhu 2006 Efficacy of karanjin and different extracts of *Pongamia pinnata* against selected insect pests. *J. Ent. Res*., **30**: 103–108

Lale, N. E. S. 1992 A laboratory study of the comparative toxicity of products from three species to the maize weevil. *Postharv. Biol. Technol*., **2**: 612 –664

Lale, A. and D. K. Kulkarni 2010 A mosquito repellent *karanj kunapa* from *Pongamia pinnata. Asian Agri–history*, **14**: 207–211

Mamun, M. S. A., M. Shahjahan and M. Ahmad 2009 Laboratory evaluation of some indigenous plant extracts as toxicants against red flour beetle, *Tribolium castaneum* Herbst. *J. Bangladesh Agri. Univ*., **7**: 1–5

Meera, B., S. Kumar and S. B. Kalidhar 2003 A review of the chemistry and biological activity of *Pongamia pinnata. J. Medic. Aroma. Plant Sci*., **25**: 441–465

Pavela, R. 2009 Effectiveness of some botanical insecticides against *Spodoptera littoralis* Boisduvala (Lepidoptra: Noctuidae), *Myzus persicae* Sulzer (Hemiptera: Aphididae) and *Tetranychus urticae* Koch (Acari: Tetranychidae). *Plant Protect. Sci*., **45**: 161–167

Poonia, S. and R. Kaushik 2013 Synergistic activity of a mixture of *Pongamia pinnata* (Karanj) and *Kigelia africana* (Sausage tree) leaf extracts against yellow fever mosquito, *Aedes aegypti. Pak. Entomol*., **35**: 1–4

Prakash, A. and J. Rao 1996 *Botanical Pesticides in Agriculture*. CRC Press, Boca Raton, FL

Roy, A., A. Mukhopadhyay, G. Gurusubramanian 2010 Field efficacy of a biopesticide prepared from *Clerodendrum viscosum* Vent. (Verbenaceae) against two tea pest in the sub *Himalyan tea* plantation of North Bengal, India. *J. Pest Sci*., **83**: 371–377

Ruberson, J. R., H. Nemoto and Y. Hirose 1998 Pesticides and conservation of natural ememies in pest management. *In* "Conservation Biological Control", ed by P. Barbosa. Academic Press, New York. pp. 207–220

Samuel, A. J. S. J., S. Radhamani, R. Gopinath, A. Kalusalingam, A. Gnana, K. A. Vimala and H. A. Husain 2009 In vitro screening of anti–lice activity of *Pongamia pinnata* leaves. *Korean J. Parasitol*., **47**: 377–380

Shoba, G. F. and M. Thomas 2001 Study if antidiarrhoeal activity of four medicinal plants in castor–oil induced diarrhoea. *J. Ethnopharmacol*., **76**: 73–76

Simin, K., Z. Ali, S. M. Khaliq–Uz–Zaman, and V. U. Ahmad 2002 Structure and biological activity of a new rotenoid from *Pongamia pinnata. Nat. Prod. Lett*., **16**: 351–357

Sridhar, S. and J. S. Chetty 1989 Effect of *Azadirachta indica* and *Pongamia glabra* leaf extracts on food utilization and modulation of efficiency of digestive enzymes in *Euprocitis fraterna* (Lepidoptra: Lymantriidae). *Proc. Indian Acad. Sci. Animal Sci*., **98**: 313–324

Tabone, E., C. Bardon, N. Desneux and E. Wajnberg 2010 Parasitism of different *Trichogramma* species and strains on *Plutella xylostella* L. on greenhouse cauliflower. *J. Pest Sci*., **83**: 251–256.

Tran, D. H. and T. Ueno 2012 Toxicity of insecticides to *Neochrysocharis okazakii*, a parasitoid of *Liriomyza* leafminers on vegetables. *J. Fac. Agric., Kyushu Univ*., **57**: 127–131

Tran, D. H., M. Takagi and K. Takasu 2004 Effects of selective insecticides on host searching and oviposition behavior of *Neochrysocharis formosa* (Westwood) (Hymenoptera: Eulophidae), a parasitoid of the American serpentine leafminer. *Appl. Entomol. Zool*., **39**: 435–441

Tran, D. H., K. P. Le, H. D. T. Tran and T. Ueno 2016 Control efficacy of pongam (*Pongamia pinnata* L.) leaf extract against the turnip aphid *Lipaphis pseudobrassicae* (Davis) (Hemiptera: Aphididae). *J. Fac. Agric., Kyushu Univ*., **61**: 141–145

Ueno, T. 2006 Current status of insect pests attacking green bunching onion in central and southern Vietnam. *J. Fac. Agr., Kyushu Univ*., **51**: 275–283

Ueno, T. 2015 Beet armyworm *Spodoptera exigua* (Lepidoptera: Noctuidae): a major pest of Welsh onion in Vietnam. *J. Agric. Environ. Sci*., **4**: 181–185

van Driesche, R. G. and T. S. Bellows 1996 *Biological Control*. New York, Chapman and Hall

Verma, M., S. Pradhan, S. Sharma, S. N Naik and R. Prasad 2011 Efficacy of karajin and phorbol ester fraction against termites (*Odontotermes obesus*). *Int. Biodeter. Biodegr*., **65**: 877–882

Yankanchi, S. R. and G. S. Lendi 2009 Bioefficacy of certain plant leaf poweder against pulse beetle *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). *Bio. Forum Int. J*., **1**: 54 –57