UNIVERSITI PUTRA MALAYSIA

EFFICACY OF FIVE INSECTICIDES AGAINST BAGWORM, Metisa plana WALKER AND THEIR SIDE EFFECTS ON OIL PALM POLLINATOR, Elaeidobius kamerunicus FAUST

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By

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Chairperson : Professor Dzolkhifli Omar, PhD
Faculty : Agriculture

Oil Palm (*Elaeis guineensis* Jacq.) is a crucial economic crop in Malaysia which has become susceptible towards pests and diseases. Studies showed that the major leaf defoliator of oil palm in Malaysia is the bagworm, *Metisa plana*. Various spraying methods had been developed for controlling the bagworms. Nonetheless, a large amount of insecticides applied were at waste due to either improper or no calibration conducted on the sprayers prior to application. The residual effects of insecticides on beneficial insects were highly concerned to preserve oil palm ecosystem. A ground study was conducted in FELDA Gunung Besout 04, Perak, with its main focus on mistblower application towards *M. plana*, and its side effects on *Elaeidobius kamerunicus*. Optimising in spraying application technique proved the effectiveness of the treatment by evaluating the operator's walking speed, spraying swath width and droplet distribution. It was concluded that 40 seconds was the optimum time required for oil palm foliar sprayed with restrictor 3. Stihl SR420 mistblower was characterised by having 1.2L / min flow rate, produced volume median diameter of 80µm, and achieved productivity of approximately of 2.58 hectares per man day. The insecticides evaluated were chlorantraniliprole (Altacor® 34.9WG), *Bacillus thuringiensis kurstaki* (DiPel® ES), cypermethrin (Hextar Cyper 5.5EC), flubendiamide (Takumi® 20WG) and *B. thuringiensis* MPOB Bt1 (Ecobac-1 EC). The insecticides application rate was based on the manufacturer's recommendation. The *M. plana* was monitored before treatment and at 3, 7, 15, 30, 45, and 70 days after treatment (DAT). Post-census showed that all insecticides were able to reduce the bagworm population below the economic threshold level (10 larvae/ frond) within 15 DAT. Both cypermethrin and MPOB Bt1 resulted in highest mortality of *M. plana* by 83%, followed by flubendiamide, chlorantraniliprole and Btk with mortality rate of 82%, 75%, and 70% respectively. The insecticides applied were able to suppress the population of *M. plana* up to 30 DAT. The side effect of insecticides on pollinating weevil, *E. kamerunicus* was also studied by monitoring the population before treatment and at 2, 4, 6 and 13 DAT. A sample population technique was designed to estimate the weevils population for every sample of male influorescence. Cypermethrin indicated the highest population declined at 2 DAT with a mortality of 92.33%, followed by *B. thuringiensis,* flubendiamide, and chlorantraniliprole with mortality of 44.50%, 30.62% and 18.19% respectively. Cypermethrin caused a significant reduction of weevil population. Whilst chlorantraniliprole, *B. thuringiensis* and flubendiamide displayed no significant reduction on the weevil population, which exhibit the characteristic of environmental friendly insecticides. Optimised mistblower application alongside the potential ecosystem friendly insecticides were recommended for sustainable control of bagworm population in oil palm.

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia
sebagai memenuhi keperluan untuk Ijazah Sarjana Sains

KEBERKESANAN LIMA JENIS RACUN SERANGGA TERHADAP SPESIS ULAT BUNGKUS, *Metisa plana* WALKER DAN KESAN SAMPINGAN KEPADA AGEN PENDEBUNGAAN SAWIT, *Elaeidobius kamerunicus* FAUST

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Kelapa sawit (*Elaeis guineensis* Jacq.,) merupakan tanaman ekonomi utama di Malaysia, namun tidak lari daripada masalah serangan musuh dan penyakit. Kajian mendapati bahawa ulat bungkus, *Metisa plana* adalah punca utama kepada kerosakan daun tanaman kelapa sawit di Malaysia. Pelbagai jenis kaedah kawalan telah wujud bagi tujuan membasmi serangan ulat bungkus. Namun, masalah ketidakperhatian terhadap aspek kalibrasi alatan menyebabkan pembaziran racun serangga berlaku ketika operasi kawalan dilaksanakan. Justeru itu, perkara ini telah memberikan impak negatif kepada kesan kawalan ulat bungkus. Selain itu, impak dan kesan sampingan racun kepada serangga berfaedah juga diambil perhatian semasa kawalan dalam memastikan kesinambungan ekosistem terjamin. Oleh yang demikian, satu kajian tapak telah dijalankan di FELDA Gunung Besout 04, Perak yang memfokuskan penggunaan aplikasi penyembur kabus terhadap *M. plana* dan kesan sampingannya kepada agen pendebungaan sawit *Elaeidobius kamerunicus*. Keberkesanan rawatan telah dibuktikan dengan mengoptimumkan kaedah teknik berjalan, ayunan semburan, dan serakan titisan semburan. Adalah disimpulkan bahawa masa yang optimum bagi tujuan semburan pelepah sawit dengan menggunakan pelaras penentu ke-tiga adalah 40 saat. Penyembur kabus Stihl SR420 mempunyai kelajuan kadar aliran air sebanyak 1.2 L/min dengan mengeluarkan jumlah diameter median titisan sebesar 80μm dan mencapai produktiviti seluas 2.58 hektar bagi seorang pekerja sehari. Kajian racun serangga chlorantraniliprole (Altacor® 34.9WG), *Bacillus thuringiensis kurstaki* (DiPel® ES), cypermethrin (Hextar Cyper 5.5 EC), flubendiamide (Takumi® 20WG) and *B. thuringiensis* MPOB Bt1 (Ecobac-1 EC) telah dilaksanakan. Kadar penggunaan racun serangga adalah berdasarkan ketetapan daripada pengeluar. Pemantauan populasi *M. plana* dilaksanakan berdasarkan bancian sebelum dan selepas pada hari ke 3, 7, 15, 30, 45, dan 70 selepas rawatan (DAT). Bancian selepas penggunaan racun menunjukkan bahawa keseluruhan racun serangga berjaya mengurangkan populasi ulat bungkus di bawah tahap ambang ekonomi (10 larva / pelepah) dalam tempoh 15 hari rawatan. Cypermethrin dan MPOB Bt1 menunjukkan kadar kematian yang tertinggi iaitu sebanyak 83%, diikuti dengan flubendiamide, chlorantraniliprole dan Btk dengan kadar kematian masing-masing adalah sebanyak 82%, 75% dan 70%. Keberkesanan racun serangga berjaya mampu mengawal populasi *M. plana* dengan berjaya sehingga hari ke 30 selepas semburan. Kajian lanjut telah dilaksanakan bagi meneliti kesan sampingan racun serangga ke atas agen pendebungaan, *E. kamerunicus* dengan memantau bancian sebelum aplikasi semburan dilaksanakan, dan selepas bancian dilaksanakan pada 2, 4, 6 dan 13 hari selepas semburan (DAT). Teknik sampel populasi telah direka bentuk untuk menganggarkan populasi kumbang pendebungaan dalam setiap sampel bunga jantan sawit yang ditetapkan. Cypermethrin menunjukkan penurunan populasi yang paling banyak dengan kadar kematian sebanyak 92.33%, diikuti dengan *B. thuringiensis*, flubendiamide dan chlorantraniprole dengan kadar kematian masing-masing adalah sebanyak 44.50%, 30.62% dan 18.19%. Cypermethrin memberikan kesan penurunan yang ketara kepada populasi kumbang pendebungaan. Manakala, racun chlorantraniliprole, *B. thuringiensis* dan flubendiamide pula tidak menunjukkan kesan yang ketara kepada penurunan populasi kumbang pendebungaan oleh kerana ciri-ciri racun serangga tersebut bersifat mesra alam. Aplikasi penyembur kabus yang terbaik bersama-sama racun serangga yang mesra alam adalah disarankan penggunaannya bagi mengawal populasi ulat bungkus di tanaman kelapa sawit.

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This thesis was submitted to the Senate of Universiti Putra Malaysia and has been accepted as fulfilment of the requirement for the degree of Master of Science. The members of the Supervisory Committee were as follows:

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Declaration by Members of Supervisory Committee

This is to confirm that:

- the research conducted and the writing of this thesis was under our supervision;
- supervision responsibilities as stated in the Universiti Putra Malaysia (Graduate Studies) Rules 2003 (Revision 2012-2013) are adhered to.

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LIST OF ABBREVIATIONS

ASABE	American Society of Agricultural and Biological Engineers
ANOVA	Analysis Of Variance
Bt	*Bacillus thuringiensis*
Btk	*Bacillus thuringiensis* kurstaki
CRD	Completely Randomised Design
DAT	Day After Treatment
EC	Emulsifiable Concentrate
EC_{50}	Effective concentration
ES	Emulsifiable Suspension
ETL	Economic Threshold Level
FELDA	Federal Land Development Authority
IPM	Integrated Pest Management
IUPAC	International Union of Pure and Applied Chemistry
LC_{50}	Lethal Concentration
MPOB	Malaysian Palm Oil Board
NaOH	Sodium hydroxide
PORIM	Palm Oil Research Institute of Malaysia
RCBD	Randomised Complete Block Design
VMD	Volume Median Diameter
WSP	Water sensitive paper
SAS	Statistical Analysis System

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CHAPTER 1

GENERAL INTRODUCTION

Oil palm (Palmae: *Elaeis guineensis Jacquin*) was originated from West Africa, and brought into South-East Asia early of the 20th Century. It was first introduced in Malaysia as an ornamental plant, originated from Bogor, Indonesia (Arnott, 1963). Development of agricultural industry has improved across the year as a result increase people's socioeconomic and lifestyle. Afterwards, Federal Land Development Authority (FELDA) has been established by Land Development Act 1956 for the purpose of introducing land settlement schemes under Group Settlement Act 1960 to the people with non-fixed income earner, poor, landless or unemployed, by planting the oil palm crop in order to eradicate the poverty. In 2016, the total area planted with oil palm was 5.74 million hectares whereby 12.3% out of the total planted area belong to FELDA (Malaysian Palm Oil Board [MPOB], 2016a).

Nonetheless, hot and humid climate as well as local policy practices replanting made on the same land. These result in susceptibility toward pests and diseases. Although various types of control applied, yet the outbreak still exist. Example of a critical pest happened nowadays is leaf eating caterpillars, comprising bagworms and nettle caterpillars. A species of bagworm, *Metisa plana,* is a major leaf defoliator of oil palm production in Malaysia (Basri, Halim & Zulkifli 1988). *Metisa plana* Walker is a native pest, which adapted with introduced African Oil Palm (Wood, 1976). It causes damage by feeding on oil palm leaves. Moderate defoliation by bagworm can cause declining in yield around 30-40% in two years (Basri, 1993). Chemical control has been used widely to prevent outbreak and to lower the bagworm population below economic threshold level (ETL). Development of Integrated Pest Management (IPM) promote the usage of selective chemical which is safe for natural enemies and so controlling the population of bagworm (Wood, 1971). There are numerous ways for applying insecticides towards the Oil Palm such as ground spraying, trunk injection, aerial spraying and root absorption. A study showed that the ground spraying method required a short period of spraying time at approximately 4.5 hours per worker to spray insecticides per hectare (Noor Hisham & Hasber, 2012). A study also reported that ground spraying application will provide higher spray deposition compared to aerial application while increasing in plant height can reduce the tendency of spray deposition (Nansen et al., 2011). Many factors need to be considered when using insecticides such as the impact on non-target organism. Consideration of non-target organism is very crucial. For example, *Elaeidobius kamerunicus* is an important pollination insect, able to increase the yield by bunch per hectare and also the oil extraction rate (OER) (Basri, Halim & Tarmizi, 1985).

Several common insecticides were evaluated for their efficiency, effectiveness toward *Metisa plana*. Two novel insecticides comprising of chlorantraniliprole and flubendiamide are believed to have a potential of environmental friendly. Therefore, the objectives of this study were:

1. To optimise the use of motorized backpack mistblower for efficient application of pesticides.

2. To evaluate the efficacy of insecticides applied using mistblower against *Metisa plana* Walker.

3. To examine the side effect of insecticides applied using mistblower on the oil palm pollinating weevil, *Elaeidobius kamerunius* Faust

REFERENCES

Aisagbonhi, C. I., Kamarudin, N., Okwuagwu, C. O., Wahid, M. B., Jackson, T., & Adaigbe, V. (2004). Preliminary observations on a field population of the oil palm-pollinating weevil *Elaeidobius kamerunicus* in Benin City, Nigeria. *International Journal of Tropical Insect, 24*(3), 255-259.

Applied Horticultural Research. (2015). Spray Application Basics. Retrieved from ahr.com.au/wp-content/uploads/2015/02/Spray-Application-Basics_Mar2015.pdf.

Arnott, G. W. (1963). The Malaysian oil palm and the analysis of its products. *Division of Agriculture Bulletin, 113*, p.32. Department of Agriculture, Federation of Malaya.

Australian Pesticides and Veterinary Medicines Authority (2009). Flubendiamide in The Product/S Belt 480 SC Insecticide & Belt 240 WG Insecticide. Retrieved from apvma.gov.au/sites/default/files/publication/13766-prs-flubendiamide.pdf.

Basri, M. W. (1984). Development of The Oil Palm Pollinator *Elaeidobius kamerunicus* in Malaysia. *Palm Oil Developments*, 2, 1-3.

Basri, M. W., Halim, A. H. & Tarmizi, A. M. (1985). Trends of oil palm yield in Malaysia as affected by *Elaeidobius kamerunicus. PT Perkebunan VI-VII*. Pusat Penelitian Marihat, Medan, Indonesia. 23-140.

Basri, M. W., Halim A. H. (1985). The effects of *Elaeidobius kamerunicus* Faust on rat control programmes of oil palm estates in Malaysia. *Palm Oil Res. Inst. Malaysia, Occ. Paper*, 14, 1-50.

Basri, M. W., Halim, A. H., & Zulkifli, M. (1988). Bagworms (Lepidoptera : Psychidae) of Oil Palms in Malaysia. *PORIM occassional paper, 23*(3).

Basri, M. W. (1993). Life History, Ecology and Economic impact of the bagworm, *Metisa plana* Walker (Lepidoptera: Psychidae) on the oil palm *Elaeis quineensis Jacquin* (Palmae) in Malaysia (Doctoral dissertation). University of Guelph.

Basri, M. W., Norman, K. & Hamdan, A. B. (1995). Natural enemies of the bagworm, *Metisa plana* Walker (Lepidoptera : Psychidae) and their impact on host population regulation*. *Crop Protection 14*(8), 637-645.

Basri, M. W & Ramlah, S. A. A. (1997). A local *Bacillus thuringiensis,* SRBT1 with potential for controlling *Metisa plana* (WLK). *Elaeis 9*(1), 34-45.

Bateman, R. P. & Jessop, N. H. H. (2008). Motorised mistblowers: their performance and rationale in developing countries. *Aspect of Applied Biology, 84,* International Advances in Pesticide Application.

Bentley, K. S., Fletcher, J. L., & Woodward, M. D., (2010). Chlorantraniliprole: An Insecticide of the Anthranilic Diamide Class. In: *Hayes' Handbook of Pesticide Toxicology,* 102, 2231-2242. doi: 10.1016/B978-0-12-374367-1.00102-6.

Bin, C.H. (1984). *Some aspects of the ecology of Elaeidobius kamerunicus Faust, the pollinating weevil of oil palm, with emphasis on developing sampling techniques* (Master's Thesis). Universiti Putra Malaysia.

Cheong, Y. L., Sajap, A. S., Hafidzi, M. N., Omar, D., & Abood, F. (2010). Outbreaks of bagworms and their natural enemies in an oil palm, *Elaeis guineensis*, Plantation at Hutan Melintang, Perak, Malaysia. *Journal of Entomology, 7*(3)*,* 141-151*.*

Chua, C. K., Ooi, K. E., Razak, A. R., Mat Arshad, M., & Marcon, P. G. (2010). Susceptibility of bagworm *Metisa plana* (lepidoptera:Psychidae) to chlorantraniliprole. *Pertanika J. Trop. Agric. Sci.*, *35*(1), 149-163.

Chua, C. K., Ooi, K. E., Razak, A. R., & Mat Arshad, M., (2011). Microstructure and Life Cycle of *Metisa plana* Walker (Lepidoptera: Psychidae). *Journal of Sustainability Science and Management, 6*(1), 51-59.

Chung, G. F. (1998). Strategies and methods for management of leaf eating caterpillars of oil palm. *The Planter, 74*(871), 531-558. Kuala Lumpur.

Corley, R.H.V & Tinker, P.B. (2003). *The Oil Palm: Fourth Edition.* Blackwell Publishing.

Corley, R.H.V. (1976). Sex differentiation in oil palm: effects of growth regulators. *J. exp. Bot.,* 27, 553-558.

Corley R. H. V & Gray B. S. (1976). Yield and yield components. In R. H. V. Corley, J. J. Hardon & B. J. Wood (Eds.), *Oil Palm Research* (pp. 77-86). Amsterdam: Elsevier.

Croft, B.A., (1990). *Arthropod Biological Control Agents and Pesticides*. New York: Wiley.

DuPont, (n.d). Altacor insect control – Technical Bulletin. DuPont Crop Protection, Wilmington, DE (2008), Retrieved from http://www.dupont.com/products-and-services/crop-protection/fruit-nut-vine-protection/products/altacor.html

Environmental Protection Agency. (1999). *Reregistration Eligibility Decision for Cypermethrin* (EPA Publication No. EPA-HQ-OPP-2005-0293-0036). Rockville, MD: U.S. Environmental Protection Agency.

Fantke, P., Gillespie, B. W., Juraske, R. & Jolliet, O. (2014). Estimating half-lives for pesticide dissipation from plants. *Environ. Sci. Technol, 48* (15), 8588-8602. doi: 10.1021/es500434p

Gage, J. C., & Seaborn, D. J. (1968). Size distribution of fine droplets produced by a mistblower. *Journal of Agricultural Engineering Research*, *13*(2), 120-126. doi: 10.1016/0021-8634(68)90087-5

Hoong, H. W. & Hoh. C. K. Y. (1992). Major pests of oil palm and their occurrence in Sabah. *The Planter, Kuala Lumpur, 68*(793), 193-210

Lahm, G. P., Selby, T. P., Freudenberger, J. H., Stevenson, T. M., Myers, B. J., Seburyamo, G., Smith, B. K., Flexner, L., Clark, C. E., & Cordova, D. (2006). Insecticidal Anthranilic Diamides: A New Class of Potent Ryanodine Receptor Activators. *ChemInform,37*(6). doi: 10.1016/j.bmcl.2005.08.034.

Malaysian Palm Oil Board. (2016a). *Oil Palm Planted Area 2016.* Retrieved from http://bepi.mpob.gov.my/index.php/my/statistics/area/176-area-2016/790-oil-palm-planted-area-as-at-dec-2016.html.

Malaysian Palm Oil Board. (2016b). *Standard Operating Procedures (SOP) Guidelines for Bagworm Control.* Malaysia : Author.

Masaki, T., Yasokawa, N., Tohnishi, M., Nishimatsu, T., Tsubata, K., Inoue, K., Motoba, K., & Hirooka, T. (2006). Flubendiamide, a Novel Ca^2 Channel Modulator, Reveals Evidence for Functional Cooperation between Ca^2 Pumps and Ca^2 Release. *Molecular Pharmacology, 69*(5), 1733-1739. doi:10.1124/mol.105.020339.

Matthews, G. A. (1985). Application from the ground. In P.T. Haskell (Eds.) *Pesticide Application: Principles and Practice* (pp. 95-117). Oxford University Press.

Matthews, G. A. (2000). Air-assisted sprayers. In *Pesticide Application Method: 3rd Edition* (pp. 216-239). Blackwell Science LTD.
Mazmira, M. M. (2013). *Influence of cultivation condition on growth, sporulation rate and endotoxin synthesis of bacillus thuringiensis MPK13* (Doctoral dissertation). Universiti Putra Malaysia.
Milner, R.J. (1994). History of *Bacillus thuringiensis*. *Agriculture, Ecosystems & Environment, 49*(1), 9-1 3. doi: 10.1016/0167-8809(94)90014-0.
Najib, M. A., Ramlah, S. A. A., Mazmira, M. M., & Basri, M. W. (2009). Effect of *Bacillus thuringiensis*, Terakil-1 and Teracon-1 against oil palm pollinator, *Elaeidobius kamerunicus* and beneficial insects associated with *Cassia cobanensis*. *Journal of Oil Palm Research, 21,* 667-674.
Nansen, C., Vaughn, K., Xue, Y., Rush, C., Workneh, F., Goolsby, J., Troxclair, N., Anciso, J., Gregory, A., Holman, D., Hammond., A., Mircov, E., Tantravahi, P., & Martini, X. (2011). A Decision-Support Tool to Predict Spray Deposition of Insecticides in Commercial Potato Fields and Its Implications for Their Performance. *Journal of Economic Entomology, 104*(4), 1138-1145. doi: 10.1603/ec10452.
Noble, R. M., & Hamilton, D. J. (1985). Stability of cypermethrin and cyfluthrin on wheat in storage. *Pesticide Science, 16*(2), 179-185. doi: 10.1002/ps.2780160212.
Noor Hisham, H., Fauzi, A. M. Z., Baharudin, K., & Rusli, A. Y. (2005). Penggunaan kaedah semburan udara untuk mengawal ulat bungkus *Metisa plana* di Felda Gugusan Gunung Besout. *Kemajuan Penyelidikan,* 45, 15-23.
Noor Farehan, I., Syarafina, R., & Idris, A. B. (2013). Toxicity of three insecticides on the predator of oil palm leaf-eater pests *Sycanus dichotomus* Stal. (Hemiptera:Reduviidae). *Academic Journal of Entomology, 6*(1), 11-19.
Noor Hisham, H., & Hasber, S., (2012). Evaluation of Several Chemical Control Approaches against Bagworm, *Metisa Plana* Walker (Lepidopterea : Psychidae) in FELDA Oil Palm Plantations. *The Planter, 88*(1040), 785-799.
Noor Hisham, H., Sukri, T. I., & Samsudin, A. (2012). Kepentingan informasi kitar hidup dan biologi ulat pemakan daun (UPD) utama di dalam menentukan tempoh rawatan kimia. *Kemajuan Penyelidikan,* 57, 19-21
Poinar, J. G. O., Jackson, T. A., Bell, N. L., & Wahid, M. B. (2002). *Elaeolenchus parthenonema* n.g.,n.sp. (nematoda: Sphaerularioidea: anandranematidae n. fam.) parasitic in the palm pollinating weevil *Elaeidobius kamerunicus* Faust, with a phylogenetic synopsis of the Sphaerularioidea Lubbock, 1981. *Systemic Parasitology, 52*, 219-225.
Ponnamma, K. (1999). Diurnal variation in the population of *Elaeidobius kamerunicus* on the anthesising male inflorescences of oil palm. *The Planter,* 881, 405-410.
Rhainds, M., Davis, D. R., & Price, P. W. (2009). Bionomics of Bagworms (lepidoptera : Psychidae). *The Annual Review of Entomology*, 54, 209-226.
Rhainds, M., & Ho, C. H. (2002). Size dependent reproductive output of female bagworms (Lepidoptera:Psychidae): implications for inter-generational variations of population density. *Appl. Entomol. Zool, 37*(3), 357-364.
Richardson, R. G. (1984). Fluorescent tracer technique for measuring total herbicides deposits on plants. *Australian Weeds*, 37, 147-151.

Smith, D. B., Burt, E. C., & Lloyd, E. P. (1975). Selection of optimum spray-droplet sizes for boll weevil and drift control. *Journal of Economic Entomology, 68* (3), 415-417.

Subramaniam, R. (1982). Report on Practical Training at Highland Research Unit. (Unpublished) Universiti Putra Malaysia, Serdang, Selangor, p.30.

Suhaimi, S. (1983). Biological studies on the oil palm pollinating weevil, *Elaeidobius kamerunicus* Faust (Curculionidae: Coleoptera). *B. Agr. Sc. Project 1982/1983*, Universiti Putra Malaysia, p.38.

Syarifah Nadiah, S., & Idris, A. (2016). Population density of oil palm pollinator weevil *Elaeidobius kamerunicus* based on seasonal effect and age of oil palm. In *AIP Conference Proceedings 1784*. American Institute of Physics. Retrieved from https://doi.org/10.1063/1.4966889

Syed, R.A. (1979). Studies on oil palm pollination by insects. *Bull. Ent. Res*., 69, 213-224.

Syed, R.A. (1980). Pollinating insect of oil palm. CIBC 1977-1980. Report. 225p.

Syed, R.A., Law, I. H., & Corley, R.H.V. (1982). Insect pollination of oil palm: Introduction, establishment and pollinating efficiency of Elaeidobius kamerunicus in Malaysia. *The Planter, 58,* 547-561.

Syngenta Crop Protection AG. (n.d.). *Water-sensitive paper for monitoring spray distribution* [Brochure]. Basel, Switzerland.

Tan, K. S. & Rao, A. N. (1979). Certain aspects of developmental morphology and anatomy of oil palm. In: *Histochemistry, developmental and structural anatomy of Angiosperms: a symposium*, pp. 267-285.

Tay, K.C. (1981). Observations on insects visiting oil palm inflorescences. Planter, Kuala Lumpur, 57, 62-81 (Reproduced from Perak Planters' Assoc. J., 1979).

Tohnishi, M., Nakao, H., Furuya, T., Seo, A., Kodama, H., Tsubata, K., Nishimatsu, T. (2005). Flubendiamide, a novel insecticide highly active against Lepidopterous insect pests. *Journal of Pesticide Science*, *30*(4), 354-360. doi:10.1584/jpestics.30.354

Tohnishi, M., Nishimatsu, T., Motoba, K., Hirooka, T., & Seo, A. (2010). Development of a Novel Insecticide, Flubendiamide. *Journal of Pesticide Science, 35*(4), 490-491. doi:10.1584/jpestics.j10-06

Valent Bioscience Corporation. (2014). *Dipel ES Biological Insecticide; Arial Application in Oil Palm* (Brochure). Australia.

Van Heel W. A., Breure C. J. & Menendez T. (1987). The early development of inflorescences and flowers of the oil palm (Elaeis guineensis Jacq.) seen through the scanning electron microscope. *Blumea, 32*, 67–78.

Wood, B.J. (1968). *Pests of Oil Palm in Malaysia and their Control*. The Incorporated Society of Planters*,* 204.

Wood, B.J. (1971). Development of integrated control programs for pests of tropical perennial crops in Malaysia. In C. B. Huffaker (Ed.), *Biological control.* 422-457. doi: https://doi.org/10.1007/978-1-4615-6528-4_19

Wood. B.J. (1976). Insect pests in South East Asia. In : R.H.V. Corley, J.J. Hardon, & B.J. Wood (Eds.), *Oil palm research* (pp.347-367). Amsterdam: Elsevier.

Wood, B. J., Corley, R. H. V. & Goh, K. H. (1973). Studies on the effect of pest damage on oil palm yield. In *Advances in Oil Palm Cultivation*. The Incorporated Society of Planters, 360-369.

World Health Organization. (1984). Data Sheet on Pesticides No 58 Cypermethrin VBC/DS/84. Retrieved from http://www.bvsde.paho.org/bvsapud/i/fulltext/cyperme58/cyperme58.htm.

Wouters, W., & van den Bercken, J. (1978). Action of pyrethroids. *General Pharmacology: The Vascular System, 9*(6), 387-398. doi:10.1016/0306-3623(78)90023-x.