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Eco Control of Agro Pests using Imaging, Modelling & Natural Predators

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Abstract

Caterpillars in their various forms: size, shape, and colour cause significant harm to crops and humans. This paper offers a solution for the detection and control of caterpillars through the use of a sustainable pest control system that does not require the application of chemical pesticides, which damage human health and destroy the naturally beneficial insects within the environment. The proposed system is capable of controlling 80% of the population of caterpillars in less than 65 days by deploying a controlled number of larval parasitoid wasps (*Cotesia Flavipes, Cameron*) into the crop environment. This is made possible by using a continuous time model of the interaction between the caterpillar and the *Cotesia Flavipes* (*Cameron*) wasps using a set of simultaneous, non-linear, ordinary differential equations incorporating natural death rates based on the Weibull probability distribution function. A negative binomial distribution is used to model the efficiency and the probability that the wasp will find and parasitize a host larva. The caterpillar is presented in all its life-cycle stages of: egg, larva, pupa and adult and the *Cotesia Flavipes* (*Cameron*) wasp is present as an adult larval parasitoid. Biological control modelling is used to estimate the quantity of the *Cotesia Flavipes* (*Cameron*) wasps that should be introduced into the caterpillar infested environment to suppress its population density to an economically acceptable level within a prescribed number of days.

Keywords: caterpillar pest control, system modelling, sustainable biological control, *cotesia flavipes* (*cameron*) wasps

References

[1] C. A. Frazier and F. K. Brown. “Insects and allergy and what to do about them,” University of Oklahoma Press. Norman, Oklahoma, 1980.

[2] L. L. Hyche “Stinging Caterpillars a Guide to Recognition of Species Found on Alabama Trees” http://www.ag.auburn.edu/enpl/bulletins/caterpillar/caterpillar.htm, February 1998.

[3] C. S. M. Malaque, L. C. Andrade, G. Madalosso, S. Tomy, F. L. Tavares, and A. C. Seguro, “A Case Of Hemolysis Resulting from contact with a Lonomia Caterpillar In Southern Brazil,” Am. J. Trop. Med. Hyg., vol. 74, no. 5, pp. 807–809, 2006.

[4] C. L Arocha-Piñango, “Fibrinolysis caused by contact with caterpillars: preliminary communication,” Acta Cient Venez vol. 18, pp. 136–139, 1996.

[5] E. M Kelen, Z. P. Picarelli and A. C. Duarte, “Hemorrhagic syndrome induced by contact with caterpillars of the *genus Lonomia* (Saturniidae, Hemileucinae),” J Toxicol Toxin Rev, vol. 14, pp. 283–308, 1996.

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[6] H. R. Brady, B. M. Brenner and W. Lieberthal, "Acute renal failure," Brenner BM, ed. The Kidney. Fifth edition. Philadelphia: W. B. Saunders Company, pp. 1200–1252, 1996.

[7] E. A. Burdmann, I. Antune, L. B. Saldanha and R.C. Abdulkader, "Severe acute renal failure induced by the venom of *Lonomia* caterpillars," Clin Nephrol vol. 46, pp. 337–339, 1996.

[8] G.P. Chikwenhere, "Status of armyworm outbreaks and control in Zimbabwe," NewsdzeZimbabwe. January 06, 2013 http://www.newsdzezimbabwe.co.uk/2013/01/armyworm-outbreak-hits- zimbabwe.html

[9] S.Wakamura, H.Yasu, M. Shimatani, T. Tokashiki, T. Okuhira, N. Fujiwara-Tsujii, M. Ishikawa, T. Uesato, H. Zukeyama and H. Tobaru, "Sex pheromone of the African armyworm Spodoptera exempta (Lepidoptera: Noctuidae): identification of components of the Okinawan population and formulation for population monitoring," Appl Entomol Zool vol. 46, pp. 415–420.

[10] F. Faithpraise, P. Birch, R. Young, J. Obu, B. Faithpraise and C. Chatwin, "Automatic plant pest detection & recognition using k-means clustering algorithm & correspondence filters", International Journal of Advanced Biotechnology and Research, vol. 4, no. 2, pp. 1052-1062, 2013.

[11] I. Kypraios, R. Young, P. Birch and C. Chatwin, "Object recognition within cluttered scenes employing a hybrid optical neural network filter," Optical Engineering vol. 43, no. 8, pp. 1839-1850.

[12] F. Faithpraise, C. Chatwin, J. Obu, R. Young and P. Birch (2013a), "Targeting the life cycle stages of the Diamond Back Moth (Plutella Xylostella) with three different parasitoid wasps," Technical Report, Sussex University, TR/SU/FF/131202, pp. 1-18, 02 Nov. 2013.

[13] F. Faithpraise, C. R. Chatwin, R. C. D. Young and P.M. Birch, (2013b) "Timely Control of Aphis craccivora Using an automatic robotic drone management system (ARDMS)," Technical Report, TR/SU/FF/130617, pp. 1-19, 17 June 2013.

[14] H. C. J. Godfray, "Parasitoids: behavioural and evolutionary ecology," USA, ISBN 0-691-03325-0, pp. 1-473, 1996.

[15] R.O.C E. Yuan, "Exhibition of Agricultural Science and Technology," ©2011 Council of Agriculture, 2011 http://flora.coa.gov.tw/view_eng.php?id=250 (Retrieved 06/03/13)

[16] K. M. Edson, S.B. Vinson, D. B. Stoltz, and M. D. Summers, "Virus in a parasitoid wasp: Suppression of the cellular immune response in the parasitoid's host," Science, 211, pp. 582-583, 1981.

[17] A. H. Grosman , A. Janssen, E. F.de Brito, E.G. Cordeiro and F. Colares, "Parasitoid Increases Survival of Its Pupae by Inducing Hosts to Fight Predators," PLoS ONE 3(6): e2276. doi:10.1371/journal.pone.0002276, 2008.

[18] F. O. Faithpraise, J. Idung, B. Usibe, C. R. Chatwin, R.Young and P.Birch, "Natural control of the mosquito population via *Odonata* and *Toxorhynchites,"* International Journal of Innovative Research in Science, Engineering and Technology, ISSN: 2319-8753, vol. 3, no. 5, pp. 12898-12911, May 2014.

[19] R. Kfir, W. A. Overholt, Z. R. Khan, and A. Polaszek, "Biology and management of economically important lepidopteran cereal stem borers in Africa," Annual Review of Entomology, vol. 47, pp. 701-731, 2002.

[20] R. P. J. Potting,"Hunting for hiding hosts: the behavioral ecology of the stemborer parasitoid *Cotesia Flavipes* (*Cameron*)," - 111. Thesis Wageningen. - With ref. - With summary in Dutch. ISBN 90-5485-551-7, 1996.

[21] Murthy K. Srinivasa and Rajeshwari R., "Host Searching Efficiency of *Cotesia Flavipes* (*Cameron*) Cameron (Hymenoptera: Braconidae) an Important Parasitoid of the Maize Stem Borer Chilo Partellus Swinhoe," Indian Journal of Fundamental and Applied Life Sciences ISSN: 2231-6345. http://www.cibtech.org/jls.htm vol. 1, no. 3, pp. 71-74, July-September, 2011.

[22] R. Tanwar, and A. Varma, "Field trials with *Cotesia Flavipes* (*Cameron*) *Cameron* against Sugar Cane Borers in sub-Tropical India," Short Communication, vol. 4, no. 3, pp. 153-156, 2002.

[23] E. I. Niyibigira, "Genetic variability in *Cotesia Flavipes* (*Cameron*) and its importance in biological control of lepidopteran stem borers," PhD Thesis, Wageningen University, pp. 162, 2003.

[24] P. Mangano,"Armyworm in Cereal Crops," Entomology Branch, Department of Agriculture and Food, South Perth. Replaces Farmnote 110/84, 1804-08/06-ID6567 ISSN 0726-934X site www.agric.wa.gov.au

[25] P. Glogoza, "The Armyworm and the Army Cutworm. North Dakota State University Agriculture and University Extension," 2000. http://www.ag.ndsu.edu/pubs/plantsci/pests/ e830w.htm (retrieved 23 /02/ 2014).

[26] J. Holt, W. Mushobozi, R.K. Day, J.D. Knight, M. Kimani, J. Njuki and R. Musebe., "A simple Bayesian network to interpret the accuracy of armyworm outbreak forecasts," Annals of Applied Biology vol. 148, pp. 141-6, 2006.

[27] A.M.A. Mahmoud, E. J. de Luna-Santillana and M. A. Rodríguez-Perez, "Parasitism by the endoparasitoid, *Cotesia Flavipes* (*Cameron*) induces cellular immunosuppression and enhances susceptibility of the sugar cane borer, Diatraea saccharalis to Bacillus thuringiensis" Journal of Insect Science 11:119 available online: insectscience.org/11.119, 2011.

[28] W. A. Hoffmann and H. Poorter, "Avoiding Bias in Calculations of Relative Growth Rate.," Annals of Botany vol. 90, no. 37, 2002. doi:10.1093/aob/mcf140

[29] V. R. Tóth, I. Mészáros, S. J. Palmer, S. z. Veres and I. Précsényi, "Nitrogen Deprivation Induces Changes in the Leaf Elongation Zone of Maize Seedlings," Biologia Plantarum , vol. 45, no. 2, pp. 241-247, 2002.
[30] H. Nelissen, B. Rymen, F. Coppens, S. Dhondt, F. Fiorani, and G. S. Beemster, "Kinematic analysis of cell division in leaves of mono- and dicotyledonous species: A basis for understanding growth and developing refined molecular sampling strategies". In Plant Organogenesis (Methods in Molecular Biology vol. 959, I. De Smet (ed.), New York, Humana Press, pp. 247-264, 2013.
[31] A. K. Hardacre, and H. L. Turnbull, "The Growth and Development of Maize (Zea mays L.) at Five Temperatures," Annals of Botany, vol. 58, pp. 779-787, 1986.
[32] F. E. Klassische, "Runge-Kutta-Formeln fünfter and siebenter Ordnung mit Schrittweiten-Kontrolle", Computing (Arch. Elektron. Rechnen) 4, pp. 93-106, 1969.
[33] J.R. Dormand, and P. J. Prince,"High order embedded Runge-Kutta formulae," J. Comput. Appl. Math. 7, no. 1, pp. 67-75, 1981.
[34] J. Butcher," Runge-Kutta methods," Scholarpedia, vol. 2, no. 9, pp. 3147, 2007.
[35] R. Schreiber, "MATLAB," Scholarpedia, vol. 2, no. 7, pp. 2929, 2007.
[36] C. Chatfield, "statistics for technology: a course in applied statistics," third edition (Revised) Chapman & Hall, London, ISBN 0-412-25340-2: pp. 327-330, 1992.
[37] B. Ostle, V. K. Turner, Jr., C.R. Hicks, & G. W. McElrath , "Engineering Statistics, the Industrial Experience," Duxbury Press, United State of America, ISBN 0-534-26538-3: pp. 161-165.
[38] F. Faithpraise, C. Chatwin, J. Obu, R. Young and P. Birch, "Pattern Recognition on Natural Control of the population density of mosquito species via Odonata and Toxorhynchites," Technical Report, University of Sussex, TR/SU/FF/131102, pp. 1-18, 02 Nov 2013.
[39] F. Faithpraise, C. Chatwin, J. Obu , B. Olawale, R. Young and P. Birch, "Sustainable Control of Anopheles Mosquito Population," Environment, Ecology & Management, vol. 3, no. 1, pp. 1-19, Feb 2014.
[40] B. Bean and P. Carl "Corn Development and Key Growth Stages", Texas A&M. Agricultural Research & Extension Centre Amarillo. osti.gov › eprints › topicpages (Retrieved 25/02/14)
[41] K. Mierzejewski (02/05/2014). "How long does it take for corn to grow?" http://www.gardeningknowhow.com/ edible/vegetables/corn/how-to-grow-corn.htm (Retrirved 20/05/2014)

Dedication

We dedicate this paper to memory of Dr Ming-Yaw Huang who completed his Doctorate with us in the United Kingdom in 1994 and subsequently worked in Taiwan as a highly innovative and adventurous Engineer.