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THE EFFECT OF PREDATORS ON THE ABUNDANCE OF THE MACADAMIA NUTBORER (*Ecdytolopha torticornis*)[1/]

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Palabras clave: *Ecdytolopha torticornis*, control biológico, depredadores, macadamia, Costa Rica.
Keywords: *Ecdytolopha torticornis*, biological control, predators, macadamia, Costa Rica.

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RESUMEN

Efecto de los depredadores en la dinámica poblacional del barrenador de la nuez de macadamia (*Ecdytolopha torticornis*). Los depredadores juegan un papel fundamental en los programas de manejo integrado de plagas; sin embargo, por lo general, son poco utilizados debido a la falta de información sobre su efecto en las poblaciones plaga. En este estudio, se cuantificó la mortalidad de larvas y pupas de *Ecdytolopha torticornis*, causada por depredadores durante el período desde la caída de la nuez hasta la cosecha, en una plantación de macadamia en Costa Rica. Se encontró que los depredadores redujeron significativamente la abundancia de larvas del barrenador de la nuez, y que la hormiga de fuego, *Solenopsis geminata* F., fue el depredador más importante.

ABSTRACT

Predators play a fundamental role in integrated pest management programmes, yet are often underutilized because of a lack of information about their effect on pest populations. In this study, the mortality of larvae and pupae of *Ecdytolopha torticornis* in a macadamia orchard in Costa Rica, caused by predators, was quantified during the period between nut fall and harvest. Predation was found to significantly reduce the abundance of nutborer larvae, and the fire ant *Solenopsis geminata* F. was considered to be the most important predator.

INTRODUCTION

Ecdytolopha torticornis Meyrick (Lepidoptera: Tortricidae) is a nutborer pest of macadamia nuts in Costa Rica, and is considered by many to be a limiting factor in macadamia production. Since it was first recorded in the country in 1987 (Lara 1987), increases in nut damage have been reported: 16% by Lara (1987), 28% by Masis and Campos (1990), and 39% by Blanco-Metzler *et al*. (1992). Direct damage to the nuts is caused by the larvae tunneling into the husks and feeding on the kernels, and indirect damage by causing early nut fall.

A number of effects of predators on reduction of pest populations have been reported: for example, mites of the Phytoseiidae on the eggs of the spiralling whitefly *Aleurodicus dispersus*

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Russell (Homoptera: Aleyrodidae) (Blanco-Metzler and Laprade 1998); coccinelids and anthocorids on *Ostrinia nubilalis* (Lepidoptera: Crambidae) (Musser and Shelton 2003); various predators on *Aphis glycines* Matsumura (Hemipetra: Aphididae) (Fox *et al.* 2004) have shown their usefulness as natural pest controllers. However, although such predators are often viewed as being beneficial, they may, as they are generalist predators, tip the ecological balance detrimentally by preying upon both the insect herbivores and other predators and parasitoids, and may also compete for food resources with other natural enemies.

In Costa Rica, macadamia nuts are harvested every 2 weeks from the ground as naturally fallen nuts. When the nuts are on the ground, the *E. torticornis* larvae and pupae present in them are potentially exposed to an increase in factors resulting in mortality. Indeed, field observations (Blanco-Metzler H.), showed differences between the number of larvae found in nuts collected directly from trees and nuts collected from the ground. The purpose of this study was to quantify the mortality of nutborer larvae and pupae during the 14 day period between nut fall and harvest, and to identify the predators.

MATERIALS AND METHODS

The field study was conducted at Oriente Farm, Turrialba, Costa Rica, at elevations ranging from 620 to 700 m. The particular macadamia tree stand was chosen because it showed the highest amount of nutborer damage within the orchards. Although the stand is a mixture of cultivars: Keahou (Haes 246), Kau (Haes 344), Kakea (Haes 508) and Keaau (Haes 660), the study was carried out only with nuts of cultivar 344 since it was reported to be the most susceptible cultivar to attack by *E. torticornis* (Blanco-Metzler 1994).

Six trees were randomly selected for the first experiment, and 10 trees for the second experiment. Quadrats, 0.5 m square, were constructed from wooden battens, each with a side height of 0.2 m. A set of 14 quadrats was placed with equal spacing in a ring under the canopy of each of the experimental trees to represent the standard harvest interval of 2 weeks, one for each day.

All the nuts from 50 cultivar 344 trees were removed from the ground for both experiments. On the following day the new nuts that had fallen naturally were harvested and sorted into those damaged by the nutborer and undamaged nuts. Only fully developed nuts were used so that differences in nut size would not affect any predators' searching behaviour. Ten damaged and 10 undamaged nuts were placed at random in each quadrat, giving a total of 1680 nuts for experiment 1 and 2800 nuts for experiment 2. The damaged nuts were marked with nail varnish to distinguish them from other nuts that would fall from the trees during the course of the experiments. Each day for 14 days, these experimental damaged nuts from one randomly chosen quadrat per tree were collected for examination. Undamaged nuts were left *in situ* to limit the disturbance to the environment of potential predators. Damaged nuts were opened in the laboratory (CATIE, Centre for Tropical Agricultural Research and Education) and the number of nutborer larvae and their instar status, and the numbers of nutborer pupae and parasitoid pupae were recorded. Daily observations of potential predator activity were also made. Data were analysed by regression analysis.

RESULTS

Three insect species were found to be preying on nutborer larvae or eggs during the time between nut fall and harvest. These species were the fire ant *Solenopsis geminata* (F) (Hymenoptera: Formicidae), the earwigs *Doru* spp. (Dermaptera: Forficulidae), and the wasp *Polybia* spp. (Hymenoptera: Vespidae). Fire ants were the most common predators, whereas the other species were only occasionally observed.

Fire ant foraging activity was observed from the second day of each study. In some cases small mounds of soil, constructed by the fire ants, were seen around the base of damaged nuts. Foragers were regularly observed wandering over the nuts, and on 2 occasions a group of 5 were seen pulling second instar larvae from the entry/exit hole that had been made through the husk by the nutborer. Noticeably from the fifth day of sampling onwards the nuts that received direct sunlight tended to dry faster than nuts in the shade and their husks split. Fire ants were observed in increased numbers near these split nuts.

In the first experiment the number of larvae decreased from 23-0 during the 14 days that the nuts were on the ground, in the second study the decrease was from 57-1. Although there was a difference in the number of developmental stages in the 2 experiments, a similar steady decline from the first day was observed (Figure 1), suggesting that there was a mortality factor that acted rapidly. The concomitant increasing numbers of fire ants observed on the ground imply that predation by these ants was largely responsible for the observed decrease in the numbers of nutborer larvae.

The daily variation in the number of nutborer larvae at each developmental stage is presented in table 1, data from the 2 experiments are pooled. Considering the duration of the different instars (Blanco-Metzler *et al.* 1993) there was evidence of recruitment to second and third instars, so part of the study population passed to the next instar during the course of each experiment. Nonetheless, in each developmental stage the numbers declined through the 14 days from nut fall to harvest, thus all stages of the life history are potentially at risk. The developmental stage that was found in highest number was the second instar (149 larvae), followed by the third instar (123 larvae), the fourth instar (92 larvae) and the first instar (67 larvae). The smaller number of first instar larvae suggests that a higher mortality factor is acting on this developmental stage. A steady decrease in the number of insects from successive developmental stages has been reported in Life Table Studies (Southwood 1987, Horn 1988).

The numbers of larvae and pupae in both studies were inversely correlated to the number of days between nut fall and harvest (r = -0.90 for first; r = -0.91 for second study; Figure 2). These results demonstrate that the nutborer larvae are actively preyed upon and that the longer the nuts are on the ground, the more likely the larvae are to be predated. Field observations indicate that fire ants are the major predator responsible.

DISCUSSION

These results demonstrate that while the macadamia nuts lie on the ground the nutborer

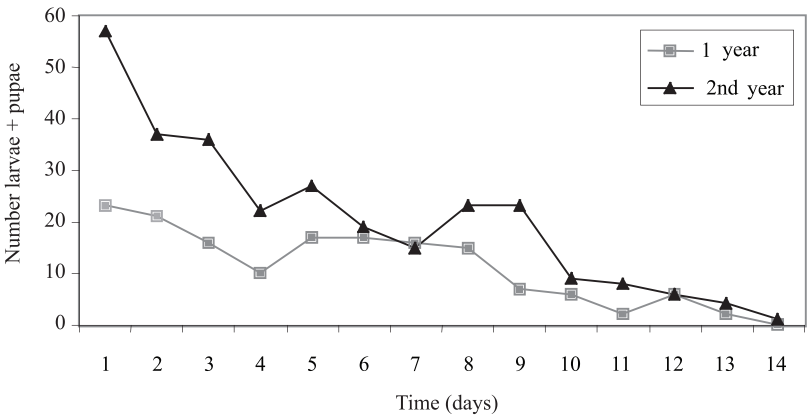

Fig. 1. The total number of macadamia nutborer larvae and pupae of *Ecdytolopha torticornis*, found in nuts on the ground between nut fall and harvest, Turrialba, Costa Rica.

Table 1. Number of *Ecdytolopha torticornis* larvae and pupae found in macadamia nuts on the ground from nut fall to harvest, Turrialba, Costa Rica.

Developmental Stage	Larval instar L1	L2	L3	L4	Pupae	Total *E.t.*
Sampling day						
1	16	26	19	16	3	80
2	15	22	8	9	4	58
3	9	15	13	15	0	52
4	9	14	4	4	0	31
5	4	12	18	10	1	45
6	4	14	13	4	1	36
7	3	12	10	6	0	31
8	5	18	8	7	1	39
9	1	8	14	5	1	29
10	1	5	3	4	2	15
11	0	1	7	2	0	10
12	0	1	4	7	0	12
13	0	1	2	2	0	5
14	0	0	0	1	0	1
Total	67	149	123	92	13	444

larvae (and pupae, albeit these are few in number) are actively predated and that the longer the nuts are on the ground, the more likely the larvae are to be attacked: consistent with the field observations implicating *S. geminata* as the main predator responsible. The observed decrease in the numbers of individuals from successive developmental stages has been reported as typical elsewhere in Life Table Studies (Southwood 1978, Horn 1988); consequently the small number of first instar larvae (16% of the total) strongly implies that this developmental stage is most at risk of predation.

However, the decrease in numbers of the nutborer larvae and pupae between nut fall and harvest is unlikely to be due exclusively to predation by ants, earwigs and wasps; other factors could affect the nutborer's ultimate abundance. Among these factors are infertile eggs, food quality, water logging, predation by rats and birds, and pathogens. Very few larvae with pathogenic symptoms were observed in the 2240 nuts examined during the study and any resulting mortality was insignificant. The effect of direct sunlight which dries out and splits the fallen nuts may have affected larval survival in various ways. Firstly, as the husk dries, its quality as food inevitably declines, and, although no evidence was found in the field or in the nuts, the larvae may also dry out or search for other, more suitable nuts in which to complete their development. La Croix and Thindwa (1986) reported a movement of *Cryptophlebia* spp. caterpillars from one fruit to another when more food was required. Yet this behaviour, if true for *E. torticornis*, would expose the nutborer larvae to an increased risk of predation. Secondly, as the nuts split, larvae are more exposed both to predators and to the effect

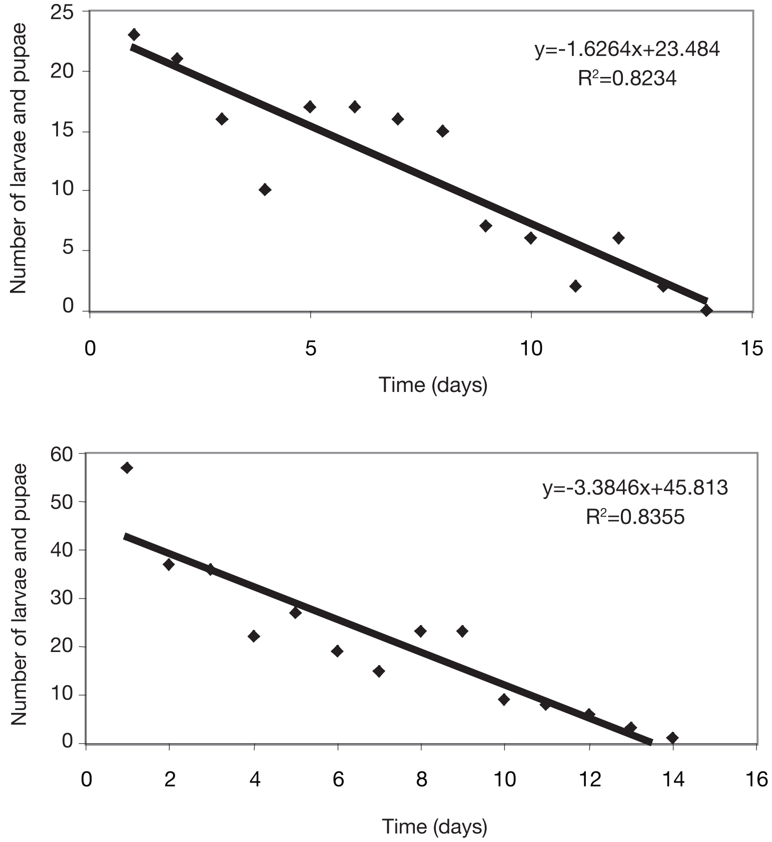

Fig. 2. The relationship between the number of macadamia nutborer larvae and the number of days the nuts were on the ground (a) first year (b) second year.

of environmental factors such as rain. Nay and Perring (2005) studied *Ectomyelois ceratoniae* (Zeller) (Lepidoptera: Pyralidae) larval mortality due to ant predation and heat load from abscised dates remaining on the tree and dates fallen to the ground. They found that abscised dates on the ground had significantly fewer live carob moth larvae than fruit that remained in bunches in the tree and attributed mortality to predation by 2 native ant species. An increase in the mortality of *Plutella* first instar larvae due to rainfall was reported by Hardy (1937) and a similar finding was made for *Pieris rapae* caterpillars by Harcourt (1966). In this study abiotic factors *per se* probably caused only a low mortality of first instar larvae before they bored into a nut, and exerted even less influence on larvae once secure inside a nut.

Many insect species are known to be good pest control agents and ants are among the most effective (Perfecto 1990); indeed, Whitcomb *et al.* (1972) consider them to be the most important predators. Ants have advantages due to the large number of individuals that comprise a colony, their predatory behaviours which are not restricted to a particular life stage of the prey, and because they may survive prey shortages by feeding on plant exudates, honeydew or stored food reserves. *S. geminata* has a neotropical distribution ranging from the southern part of the United States to South America and the Caribbean. In a study of a maize-squash ecosystem, Risch and Carroll (1982) found that this fire ant significantly reduced the numbers and diversity of other arthropods, and Andrews (1988) reported that this ant and the yellow stripped earwig *Doru taeniatum* are good candidates for controlling the fall armyworm *Spodoptera frugiperda* (Lepidoptera: Noctuidae) in Central America.

The typical foraging pattern of the fire ant is an overdispersion of nest sites affording a more uniform coverage of the ground and, thus, a better chance of finding a food source (Hölldobler and Wilson 1990). Pertinently these fire ants are primarily terrestrial foragers (Risch 1981) and will encounter fallen nuts. Whilst nutborer larvae and pupae are an easy source of food since they are essentially immobile, they are concealed and require to be found. In this, the ants may be helped by odours produced either by the prey or by the damaged nuts. Horn (1988) suggested that the interactions between phytophagous insects and their host plants might influence the activity and effectiveness of parasitoids and predators, that natural enemies may use chemical cues from plants to locate potential prey. Whether this is true in this case remains an interesting open question.

Many studies report that ants are density-responsive predators which can, therefore, concentrate on localized pest populations. The pheromone recruitment behaviour of many ants, including *S. geminata*, makes the density-responsive component of foraging very efficient relative to that of other foragers (Carroll and Risch 1983). However, due to the habit of *E. torticornis* of living inside a nut, it is probable that fire ants affect a density-independent mortality. Although the fire ants are numerous with well established nests, since they are generalist predators they are unlikely to concentrate their feeding activity on dense patches of nutborer larvae. This inference is consistent with Stiling's (1987) opinion that since polyphagous predators do not rely on one prey species alone, they are unlikely to impose density-dependent mortality. A similar argument is presented by Münster-Swendsen (1980) who found that spiders caused the same level of mortality irrespective of prey density, and Freeman and Smith (1990) who studied predation of the leafmining fly *Liriomyza commelinae* (Diptera: Agromyzidae) by the ant *Crematogaster brevispinosa* Mayr and concluded likewise.

Finally, Jones *et al.* (1992) suggested that as macadamia nuts are harvested once a month in Hawaii, a shorter havest interval might minimise damage caused by the macadamia shotborer *Hypothenemus obscurus* (F) (Coleoptera: Scolytidae). While, conversely, an increase in the interval between nut fall and harvest could decrease the nutborer populations, it is not a practical recommendation in Turrialba where high temperatures and rainfall cause a rapid decrease in nut marketable qualities.

This study shows that predation of larvae whilst the macadamia nuts are on the ground significantly reduces the abundance of *E. torticornis*; and of the 3 insect species identified as predators: the earwig *Doru* spp., the wasp *Polybia* spp. and the fire ant *S. geminata* the latter is the most important. Other potentially detrimental factors such as rain, the quality of the food or pathogens had no apparent effect on the nutborer's survivorship during the period between nut fall and harvest.

LITERATURE CITED

ANDREWS K.L. 1988. Latin American research on *Spodoptera frugiperda* (Lepidoptera: Noctuidae). Florida Entomologist 71:630-654.

BLANCO-METZLER H. 1994. The biology and ecology of the macadamia nutborer *Ecdytolopha torticornis* in Costa Rica. Ph.D. Thesis, University of Edinburgh, Scotland. 132 p.

BLANCO-METZLER H., WATT A. D., COSENS D. 1993. Ciclo de vida y comportamiento de oviposición de *Ecdytolopha torticornis* Meyrick (Lep:Tortricidae) barrenador de la nuez de macadamia. Revista Manejo Integrado de Plagas No. 29:36-39.

BLANCO-METZLER H., WATT A. D., SHANNON P. Dynamics of macadamia nut damage by *Ecdytolopha torticornis* (Lep: Tortricidae) and parasitism by *Apanteles* spp. *In:* Individuals, Patterns, and Populations (Norewich, England, 7-10 September, 1992).

BLANCO-METZLER H., LAPRADE S. 1998. Enemigos naturales de la mosca blanca *Aleurodicus dispersus* Russell (Homoptera: Aleyrodidae): parasitoides y depredadores. Agronomía Mesoamericana 9(2):41-44.

CARROLL C.R., RISCH S.J. 1983. Tropical annual cropping systems: ant ecology. Environmental Management 7(1):51-57.

FOX T.B., LANDIS D.A., CARDOSO F., DIFONZO C.D. 2004. Predators suppress *Aphis glycines* Matsumura population growth in soybean. Environmental Entomology 33(3):608-618.

FREEMAN B.E., SMITH D.C. 1990. Variation of density-dependence with spacial scale in the leaf-mining fly *Liriomyza commelinae* (Diptera: Agromyzidae). Ecological Entomology 15:265-274.

HARCOURT D.G. 1966. Major factors in survival of the immature stages of *Pieris rapae* (L). Canadian Entomologist 112:375-385.

HARDY. 1937. *Plutella maculipennis*, Curt., its natural and biological control in England (unpublished).

HÖLLDOBLER B., WILSON E.O. 1990. The ants. Massachusetts, Harvard University Press. 732 p.

HORN D.J. 1988. Ecological approach to pest management. Guilford Press, New York. 285 p.

JONES V.P., BURNAM-LARISH L., CAPRIO L.C. 1992. Effect of harvest interval and cultivar on damage to macadamia nuts caused by *Hypothenemus obscurus* (Coleoptera: Scolytidae). Journal of Economic Entomology 85(5):1878-1883.

LA CROIX E.A.S., THINDWA H.Z. 1986. Macadamia pests in Malawi. III. The major pest. The biology of bugs and borers. Tropical Pest Management 32(1):11-20.

LARA F. 1987. Studies on *Cryptophlebia leucotreta* (Meyrick) (Lepidoptera: Tortricidae) on macadamia in Costa Rica. Siquirres, Costa Rica, Macadamia de Costa Rica. 8 p. (Consultancy Report)

MASÍS C.E., CAMPOS L.F. 1990. Observaciones: taladrador de la nuez (*Ecdytolopha torticornis)*. San José, Universidad de Costa Rica. 11 p. (Unpublished)

MÜNSTER-SWENDSEN M. 1980. The distribution in time and space of parasitism in *Epinotia tedella* (Cl) (Lep: Tortricidae). Journal of Animal Ecology 5:373-383.

MUSSER F.R., SHELTON A. 2003. Predation of *Ostrinia nubilalis* (Lepidoptera: Crambidae) eggs in sweet corn by generalist predators and the impact of alternative foods. Environmental Entomology 32(5):1131-1138.

NAY J.E., PERRING T.M. 2005. Impact of ant predation and heat on carob moth (Lepidoptera: Pyralidae) mortality in California date gardens. Journal of Economic Entomology 98(3):725-731.

PERFECTO I. 1990. Indirect and direct effects in a tropical agroecosystem: the maize-pest-ant system in Nicaragua. Ecology 71(6):2125-2134.

RISCH S.J. 1981. Ants as important predators of rootworm eggs in the neotropics. Journal of Ecological Entomology 29:299-320.

RISCH S.J., CARROLL C.R. 1982. Effect of a keystone predaceous ant *Solenopsis geminata*, in a non equilibrium community. Ecology 63:1979-1983.

SOUTHWOOD T.R.E. 1978. Ecological methods with particular references to the study of insect populations. 2nd. ed. London, Chapman and Hall. 524 p.

STILING P.D. 1987. The frequency of density-dependence in insect host parasitoid systems. Ecology 68:844-856.

WHITCOMB W.H., DENMARK H.A., BHATKAR A.P., GREEN G.L. 1972. Preliminary studies on the ants of Florida soybean fields. Florida Entomologist 55:129-142.