SEASONAL OCCURRENCE OF THE POWDERPOST BEETLE, *DINODERUS MINUTUS*, IN THE PHILIPPINES

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GARCIA, C. M. & MORRELL, J. J. 2008. Seasonal occurrence of the powderpost beetle, *Dinoderus minutus*, in the Philippines. The incidence of *Dinoderus minutus* was evaluated over 24 months at the Makiling Forest Reserve Experimental Site (MFRES) in Laguna and 18 months at Kawayan Farm Experimental Site (KFES) in Rizal province using shelter traps. Beetle abundance was studied in relation to starch and moisture contents of bamboo, temperature, relative humidity, site elevation, rainfall and wind speed. The data were used to develop prediction models for beetle occurrence on freshly cut bamboo. Populations peaked from February to early June and declined or disappeared in the rainy season (July–October). Bamboo starch and moisture contents, temperature and relative humidity influenced *D. minutus* occurrence at MFRES, whereas only starch content and temperature significantly affected populations at KFES. Starch content best explained the variation in *D. minutus* occurrence at both sites. However, the direct relationship between temperature and starch production could also allow temperature to be used to predict beetle populations. The other factors were poorly correlated with beetle occurrence at both sites. Monitoring with shelter traps has considerable potential for managing bamboo harvesting to limit powderpost beetle attack.

Keywords: Seasonal abundance, temperature, bamboo starch content, insect sampling, population density

GARCIA, C. M. & MORRELL, J. J. 2008. Kejadian bermusim kumbang bubuk *Dinoderus minutus* di Filipina. Insidens *Dinoderus minutus* dinilai selama 24 bulan di Tapak Eksperimen Hutan Simpan Makiling (MFRES) yang terletak di Laguna dan selama 18 bulan di Tapak Eksperimen Kebun Kawayan (KFES), Rizal menggunakan perangkap lindung. Kelimpahan kumbang dikaji berbanding kandungan kanji, kandungan lembapan buluh, suhu, kelembapan relatif, aras tapak, hujan dan kelajuan angin. Data yang dikumpul diguna untuk membangunkan model bagi meramal kejadian kumbang pada buluh yang baru dipotong. Populasi kumbang paling tinggi dari Februari hingga awal Jun dan menurun atau hilang terus semasa musim hujan (Julai–Oktober). Kandungan kanji buluh, kandungan lembapan, suhu dan kelembapan relatif mempengaruhi kejadian *D. minutus* di MFRES manakala hanya kandungan kanji dan suhu mempengaruhi populasi di KFES. Perbezaan kejadian *D. minutus* di kedua-dua tapak dapat dijelaskan dengan baik melalui kandungan kanji. Bagaimanapun oleh sebab terdapat hubungan langsung antara suhu dengan penghasilan kanji maka suhu boleh juga diguna untuk menentukan populasi kumbang. Hubungan faktor lain dengan kejadian kumbang di kedua-dua tapak adalah tidak begitu ketara. Pemantauan dengan perangkap lindung merupakan pilihan yang baik dalam menguruskan penuaian buluh untuk mengehadkan serangan kumbang bubuk.

INTRODUCTION

Powderpost beetles (*Dinoderus minutus*) are a major post-harvest problem throughout the Philippines. This beetle is cosmopolitan in the archipelago and attacks numerous harvested plants, including many bamboo species.

Over the years, chemical treatment has been the primary approach for controlling *D. minutus* infestation. Extreme reliance on chemicals creates the potential for development of insect resistance, inadvertent elimination of natural enemies and non-target organisms and potential environmental problems (David & Somasundaram 1985, Dinham 1993, Philp 1995, Smith 1996, Dureja & Parmar 1998, Suk *et al.* 2003).

The post-harvest problems posed by *D. minutus* underscore the need for more effective combinations of cultural, biological, chemical

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and non-chemical methods to alleviate or minimize pest problems (Croft & Hoyt 1983, Pedigo 1998, Dent 2000, Speight & Wylie 2001, Walter 2003). The implementation of more ecologically-based control strategies requires development of a better understanding of the life-cycle, habits, behaviour and population dynamics of the beetle and the climatic factors that may influence beetle occurrence.

This study examined the influence of various microclimate and bamboo characteristics on population abundance of *D. minutus* at two sites in Philippines.

MATERIALS AND METHODS

Experimental sites

The relative population size of *D. minutus* was assessed at two experimental sites at different elevations.

The Makiling Forest Reserve Experimental Site (MFRES)

The Makiling Forest Reserve Experimental Site (MFRES), 800 m asl, was designated as the high-elevation experimental site. It is 65 km south-east of Manila City and located within the 4244-ha Makiling Forest Reserve of the University of the Philippines at Los Baños in Laguna. It contains various valuable plant species including bamboo stands. The vegetation ranges from mixed dipterocarps to mossy forest (Cruz *et al.* 1991).

The Kawayan Farm Experimental Site (KFES)

The Kawayan Farm Experimental Site (KFES), the low-elevation experimental site, is as 20-ha private bamboo plantation 100 m asl. It was established in 1970 in Pililla, Rizal 58 km east of Manila City. The farm is planted primarily with several species of bamboo including *Bambusa vulgaris* and *B. blumeana*; the other vegetation is predominantly cogon grass *(Imperata cylindrica)*. Fruit-bearing trees such as avocado *(Averrhoa carombola)*, mango (*Mangifera* sp.), star apple *(Chrysophyllum caimito)*, papaya *(Carica papaya)*, banana *(Musa* spp.), santol *(Sandoricum koetjape)*, sineguelas *(Spondiae purpurea)* and guava *(Psidium guajava)* are also cultivated on the bamboo plantation.

Sampling

Shelter traps (0.6 × 0.6 × 1.2 m) were fabricated from lumber. The roof was overlaid with a yellow plastic canvas without walls while the floor consisted of 25 mm × 50 mm × 0.6 m long wooden slats (Figure 1). The footings of the traps were placed in 1-litre containers half-filled with used engine oil to protect the trap and bamboo baits against attack by other intruders such as ants and termites. Three shelter traps were installed at each site. Twenty pieces of bait were arranged in four stacks of five equally-spaced baits oriented in alternating directions for each shelter trap.

Traps were installed randomly at least 100 m apart underneath the bamboo canopy along the edges of bamboo clumps at each site. Traps were inspected two weeks after installation, then all bamboo baits were retrieved and new baits were installed at monthly intervals thereafter.

Preparation of bamboo baits

Three-year-old defect-free culms of kauayan-kiling *(Bambusa vulgaris)*, a bamboo species susceptible to beetle attack, were felled monthly and served as natural baits for the traps. All the baits used at both sites were obtained from KFES during the sampling period.

Bamboo baits measuring 25 × 300 mm were prepared from the mid-portion of the culm at internode numbers 10 to 15 from the butt. The starch and moisture content of the baits were determined from samples taken from the same portion of the culm used for baiting at each time point.

Figure 1 Example of a shelter trap used to collect *Dinoderus minutus* adults

Determination of moisture content

Average monthly moisture content of the bamboo baits was determined by sawing 10 samples (25 mm long × 25 mm in diameter) from the mid-portion of the same culm used for baiting and starch analysis. Each piece was immediately weighed with a portable battery-operated LS200 balance (Ohaus, Forham Park, NJ), oven-dried at 100 °C to constant weight and re-weighed.

Determination of starch content

The starch content of the bamboo baits during the sampling period was analyzed according to the method of Humphrey and Kelly (1961). Samples (25 mm thick) were sawn from the same portion of the culm used for baiting and chopped into match-stick size sections that were air-dried and ground to pass a 200-mesh sieve.

A 0.4-g oven-dried sample from each treatment was weighed (Mettler-Toledo PB 303, AG 1993, Columbus, Ohio) into a 50-ml beaker to which 10 ml of 7.2 M perchloric acid was added. The acid was allowed to react for 10 min under constant stirring. The contents of the beaker were transferred to a 50-ml volumetric flask, brought to volume with distilled water and centrifuged for 5 min at 5000× g. After centrifuging, a 10-ml aliquot was poured into a 50-ml volumetric flask along with 2–3 drops of phenolphthalein and 4 ml 2 N NaOH. When the pinkish colour disappeared, 3 ml acetic acid, 1 ml 10% w/v potassium iodide and 5 ml 0.01 N potassium iodate were added. Colours ranging from light to dark blue were allowed to develop for 15 min before bringing to volume. Absorption was measured at 650 nm with a M330/230 spectrophotometer (Camspec, Cambridge, UK). Starch contents were determined by comparison with prepared standards.

Estimation of *D. minutus* abundance

Abundance of *D. minutus* was estimated monthly for 24 months (March 1998–June 1999, November 1999–June 2000) at MFRES and 18 months (January 1998–June 1999) at KFES.

The baits were placed in individual plastic bags and brought back to the laboratory, where adult beetles were counted both by visual inspection and by dissection of the bamboo bait with a sharp knife. The number of captured beetles was used as an estimate of *D. minutus* abundance.

Determination of temperature, relative humidity, rainfall and wind speed

The daily minimum and maximum temperatures and relative humidity at each experimental site were recorded with an indoor/outdoor hygrometer (Radio Shack, Fort Worth, Texas). Rainfall and wind speed data were obtained from the records of the Agromet Stations at IRRI, Los Baños, Laguna. Records for MFRES were obtained at the IRRI Main Agromet Station in Los Baños, whereas data for KFES were taken at the IRRI Siniloan Agromet Station in Siniloan, Laguna. These stations were 5 and 10 km from the MFRES and KFES sites respectively.

Data analysis

The effects of bamboo starch and moisture contents and of climatic factors on *D. minutus* population size were analyzed by Pearson's correlations and multiple regression analyses (SAS Institute 2001). Stepwise regression was applied to determine the factors most closely associated with beetle population and to determine the regression model that best predicted population abundance at each site. The final models from each site were then combined to derive the best regression model for the two locations.

RESULTS AND DISCUSSION

Relative abundance of *D. minutus* at MFRES and KFES

Dinoderus minutus populations at the MFRES site began to increase in March, with the highest numbers recorded between April and June 1998 (Figure 2). The population was markedly reduced in July, and no beetles were collected from August to October. Beetles appeared again in November, but were absent from December to February 1999. The pattern of beetle abundance followed this same cycle in 1999 and 2000, but the populations were lower than those in 1998.

The relative abundance of *D. minutus* at KFES varied in a manner similar to that recorded at MFRES. Beetles were most abundant in March to June in 1998, then declined drastically and remained low from July to August. No beetles were collected in September and October, but population appeared to increase in November and then declined in December. In 1999, the initial population started to build up as early as February and peaked in May. As at MFRES, more beetles were collected in 1998 than in 1999. Understanding the reasons for variations in beetle frequency may help to identify tools for indirectly predicting the risk of beetle attack. This data could then be used to time harvesting to avoid high beetle populations or to determine when treatments may be most efficacious. We examined the relationships between trapping frequency and bait moisture content, bait starch content or temperature for this purpose.

Relationship between *D. minutus* captured and temperature

Beetle populations tended to vary with temperature levels at both sites, although the increases were not always simultaneous (Figure 2). The highest temperatures were recorded from March to June, and the lowest temperatures occurred from December to February. Collection of most *D. minutus* adults coincided with the highest temperature range (March to early June).

Peak beetle populations and the highest mean temperature at MFRES were recorded in April and May 1998. This trend was the same in 1999 and 2000, although fewer beetles were collected. Lower temperatures during the dry season in 1999 and 2000 may have accounted for the lower beetle occurrence.

Mean temperature range at KFES was higher than at MFRES and may have accounted for the higher number of beetles captured. Beetle captures increased from March to May, when mean temperatures and starch content were also high, and declined from June to August, when temperature and starch contents decreased. The slightly higher mean temperatures at KFES may have accounted for the higher beetle occurrence in November 1998.

The higher temperature and longer dry season in 1998 provided more favourable conditions for beetle development at both sites. The correlation coefficients (MFRES, $r = 0.61$, $p < 0.0001$; KFES, $r = 0.52$, $p = 0.04$) indicated a somewhat linear relationship between the *D. minutus* population and temperature, suggesting that beetle population increased as temperature increased. Thus, temperature monitoring may be simpler than measuring bamboo starch content for monitoring the risk of powderpost beetle attack.

Relationship between *D. minutus* captured and bamboo starch content

The highest beetle populations tended to occur when starch content was also higher (Figure 3). Starch content varied with the season and peaked during summer when photosynthetic activity was at its peak. The amounts of starch in culms during the rainy season were less than half of those measured during the summer.

Beetle population increases tended to be associated with increased bamboo starch content at three of the four times when beetle populations increased. The reason for the increased beetle population in November 1998 was unclear since it was not associated with any changes in the other parameters assessed (moisture content, starch content or temperature). The presence of beetles at this time suggested that *D. minutus* could still attack bamboo with lower starch contents under favourable environmental conditions.

A Pearson's correlation analysis showed strong evidence that the annual increases in population density were associated with the seasonal variation in the bamboo starch content during the sampling period (MFRES, $r = 0.77$, $p < 0.0001$; KFES, $r = 0.74$, $p = 0.0009$). Clearly, the suitability of the substrate for insect development was closely tied to the insect life cycle. A number of other researchers have noted similar relationships between starch content and degree of beetle attack on a number of species (Plank & Hageman 1951, Joseph 1958, Dhamodaran *et al.* 1986, Bhat *et al.* 2005).

Although both starch content and temperature were strong predictors of beetle population, starch content masked the variance contributed by temperature. Regression of predictors against the number of beetles captured showed that starch content explained 74% of the variation at KFES in beetle abundance and 77% at MFRES compared with 52 and 61% respectively explained by temperature. Starch content was the primary

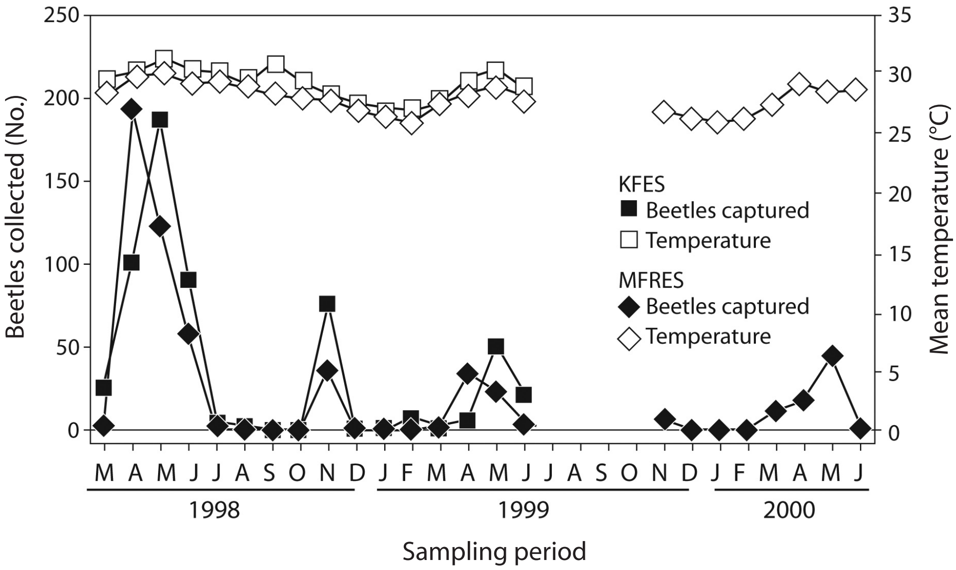

Figure 2 Relationship between beetles captured and average monthly temperature at MFRES and KFES

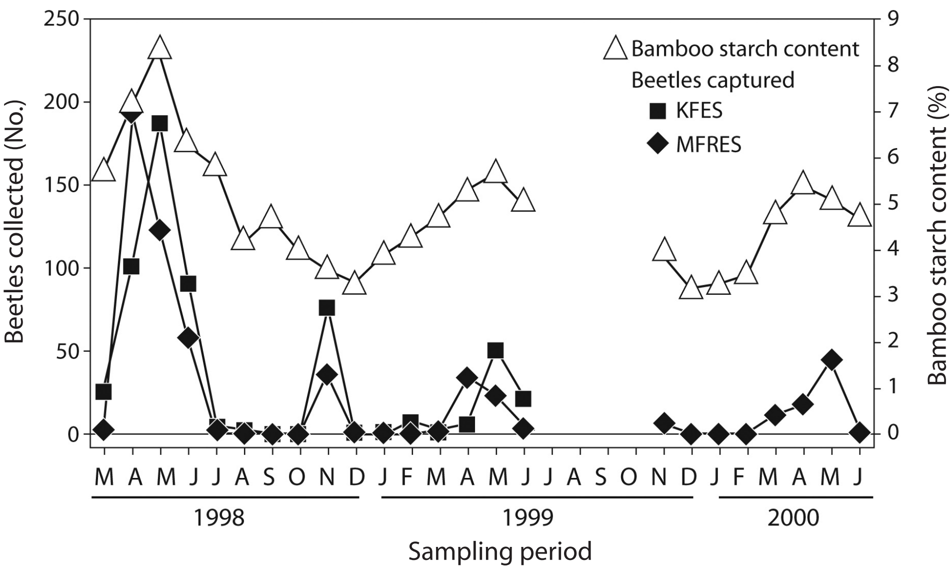

Figure 3 Relationship between beetles and bamboo starch content of bamboo baits at MFRES and KFES

factor considered in the development of a final model to predict beetle population (Y). The final model for the two experimental sites was:

$$\text{Mean Y/starch} = -106.57 + 27.43 \text{ (\% starch content)} \quad (p < 0.001)$$

Relationship between *D. minutus* captured and bamboo moisture content

More *D. minutus* were captured from March to May when the moisture content of bamboo ranged from 63 to 126% during the sampling period at MFRES (Figure 4). The beetle population peaked in April and May and started to fluctuate before the start of the rainy season (June). No beetles were captured during the heavy rainy season (August to October) when bamboo moisture content ranged from 112 to 149%. Although there was moderate evidence that the beetle populations were inversely correlated with bamboo moisture content at the MFRES site (r = -0.51, p = 0.01), beetle populations at KFES appeared to be poorly correlated with bamboo moisture content (data not shown) (r = -0.47, p = 0.06).

Relationship between *D. minutus* captured, relative humidity and other environmental factors

Relative humidity ranged from 74 to 91% over the 24-month trapping period at MFRES (Figure 5). Relative humidity between March and June increased from 74 to 83% in 1998, 81 to 84% in 1999 and 82 to 84% in 2000. As expected, relative humidity increased during the rainy season (July to December), regardless of the year. Beetles were present when relative humidity was low (March to June) and absent as relative humidity increased. Populations tended to fluctuate or diminish early in the rainy season (July to October).

There was a strong inverse relationship between beetle population and relative humidity at MFRES (r = 0.72, p < 0.0001), but not at KFES (r = 0.37, p = 0.15). Relative humidity could affect substrate suitability by allowing competing microorganisms to alter the substrate or could favour beetle predators, but any effects appeared to be variable and were probably not reliable predictors of beetle attack.

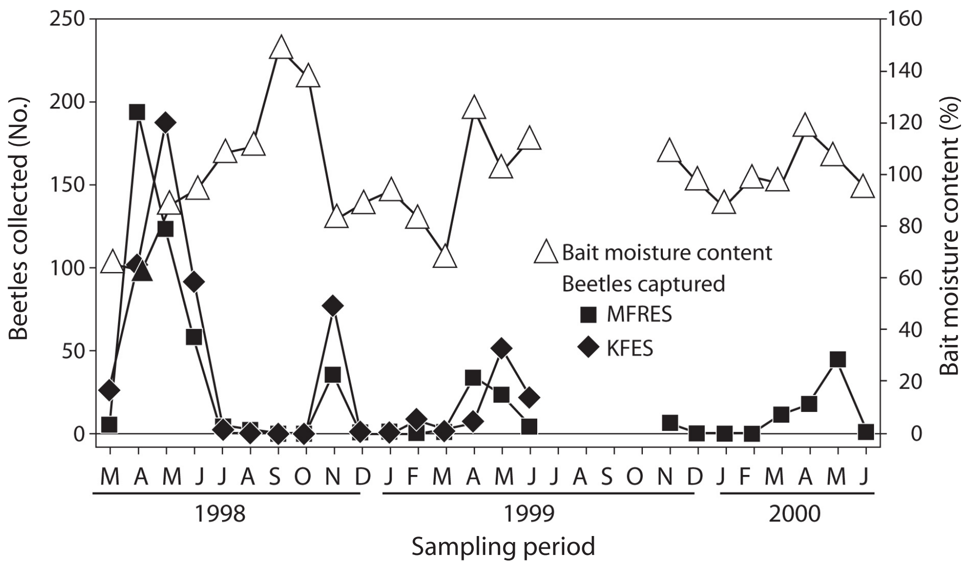

Figure 4 Relationship between beetles captured/month and bamboo bait moisture content at MFRES and KFES

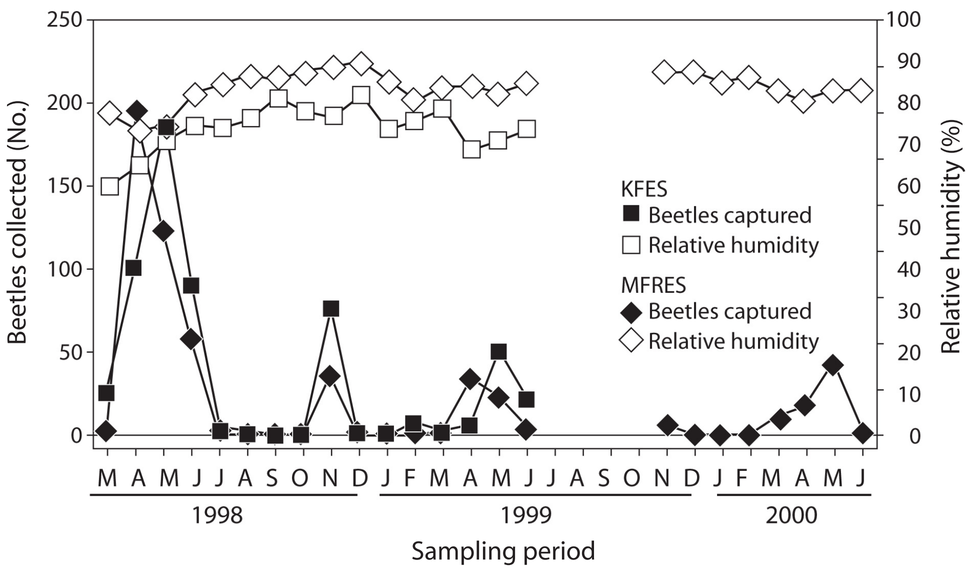

Figure 5 Relationship between *D. minutus* and average relative humidity at MFRES and KFES

Rainfall amount (MFRES, r = -0.32, p = 0.12; KFES, r= -0.18, p = 0.50), wind speed (MFRES, r = 0.22, p = 0.29; KFES, r= -0.08, p = 0.77), or site elevation (p = 0.24) did not appear to be related to beetle incidence at either site.

CONCLUSIONS

Shelter traps provided a useful method for monitoring bamboo powderpost beetles and may also be used in conjunction with starch levels or mean temperature to predict the potential for beetle damage to freshly cut bamboo. These predictions can be used to time harvesting or application of control measures. Peak beetle occurrence during the summer months (February to early June) suggests that bamboo harvested then will be prone to heavy infestation by powderpost beetles. Harvesting bamboo either early (July to October) or late in the rainy season (January and December) could avoid powderpost beetle infestations.

Although bamboo starch content was an excellent predictor of beetle abundance, its field application might be economically and technically difficult for bamboo farmers, owners or users. The direct relationship between temperature and starch production suggests that temperature might also be used to predict beetle population. Temperature is easily monitored and forecasts can be determined a week or a month in advance. Thus, calendar harvesting, coupled with trapping and temperature data, could be used in bamboo post-harvest management programmes to limit beetle infestation. However, additional information will be needed to develop an integrated strategy for managing *D. minutus*, including information on seasonal starch content and temperature at other plantation sites.

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