Estimation of the population density of the sweetpotato weevils on the Mariana Islands

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Abstract

The sweetpotato *Ipomoea batatas* L. (Convolvulaceae) has been one of the most important foods for Pacific islanders for centuries. However, the yield levels have been declining in the recent past due to the presence of sweetpotato weevils *Cylas formicarius* (Fabricius) (Coleoptera, Brentidae), *Euscepes postfasciatus* (Fairmaire) and *Daealus tuberosus* (Zimmerman) (Coleoptera, Curculionidae). Therefore, urgent management or eradication methods are sought in the Mariana Islands (Guam, Rota, Saipan, and Tinian). However, the management or eradication of these weevil pests requires accurate assessments of the target pest density. Currently, no advice is provided to growers on the best method for sampling sweetpotato for weevil pests, although pheromone-based traps or chemicals are being used. This study defines the results of field counts designed to adjust relative sampling techniques for three sweetpotato weevil pests by inspecting plants visually and at random in the field with an absolute measure of population density. Significant relationships were detected between the relative four sampling sites between the three weevil pests. In the dry and wet season, 90% and 35.5%, respectively, of population density of *C. formicarius* was noticed in Rota. This density of the population levels of this species is significantly lower in Saipan, Guam and Tinian. No incidence of *E. postfasciatus* and *D. tuberosus* was observed on Guam. However, *E. postfasciatus* is identified as the second most destructive pest in Rota, Tinian and Saipan in both the dry and wet seasons. Likewise, *D. tuberosus* is the third major pest as the recorded population density ranged from 12.5% to 2.5%. Also, it is evident from the sampling study that the population densities of all three weevils are significantly higher in the dry season than the wet season.

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Introduction

Sweetpotato, *Ipomoea batatas* L. (Convolvulaceae) has been an important crop and has been used as food for several centuries (O'Brien, 1972). It is believed to have originated in tropical America and spread extensively to other climatically suitable areas in the tropics, subtropics and even in warmer areas of the temperate zone (Yen, 1982). This crop is also considered to be the sixth most important crop in the world, after wheat, rice, maize, white potato and barley (Vietmeyer, 1986). Nearly 92% of the sweetpotato crop is produced in Asia and the Pacific islands (Chalfont *et al*., 1990). Sweetpotatoes also contain significant levels of protein in addition to carbohydrates (Loebenstein and Thottappilly, 2009). However, recent years have seen a gradual decrease in the areas under sweetpotato cultivation. Sweetpotatoes are in the same family as Morning Glories (*Ipomoea* spp.) and its leaves resemble the leaves of the sweetpotato vines (Austin *et al*., 1991). Although the amount of sweetpotato produced per capita declined in USA up till 2006, the total area of cultivation and amount per capita produced has been increasing (Economic Research Service, 2011).

The sweetpotato has been a staple food for Pacific islanders for centuries and is the most widely produced crop (Nandawani and Tudela, 2010). Sweetpotato is considered an important food crop in the Mariana Islands. This crop is grown continuously throughout the year. However, its total harvested area and productivity is declining due to high infestation of the sweetpotato weevils, *Cylas formicarius* (Fabricius) (Coleoptera, Brentidae), *Euscepes postfasciatus* (Fairmaire) (West Indian sweetpotato weevil) and *Daealus tuberosus* (Zimmerman) (Coleoptera: Curculionidae) (Zimmerman, 1948) (Figure 1). Although *C. formicarius* is a major pest of cultivated sweetpotatoes, it is also a pest of stored sweetpotatoes. However, *E. postfasciatus* and *D. tuberosus* are also well-known as post-harvest pests of sweetpotatoes. Many farmers and homeowners spray toxic pesticides to control these weevils. Since the grubs bore inside the tubers and the vines, and the adults are nocturnally active, the chemicals have been shown to reduce the weevil population with variable degrees of success (Jansson *et al*., 1987; Chalfont *et al*., 1990). Although pheromone-based traps would be useful in estimating the population levels, monitoring and controlling these weevils, the pheromone compounds have only been identified and used for *C. formicarius* (Jackson and Bohac, 2006). However, trap catches are known to be affected by weather, topographical conditions and/or flora. Cultural controls, such as the use of resistant cultivars of *I. batatas*, non-infested planting material and crop rotation, along with various management systems have been shown to reduce pest numbers (Jansson *et al*., 1987; Chalfont *et al*., 1990).

Approximately 30 alternative wild hosts have been recorded as sweetpotato weevil hosts, particularly for *C. formicarius* and multiple species of *Ipomoea* (Hill, 1983). Reports of wild hosts of *E. postfasciatus* are very limited, probably due to its restricted distribution. In the Mariana Islands, Littlebell and Aiea Morning Glory, *Ipomoea triloba* L. (Convolvulaceae) are widespread and serve as alternative hosts for *C. formicarius*. This vine is reported to grow around sweetpotato fields and has been recorded as an alternate host of *E. postfasciatus* (Pemberton, 1943). Interestingly, both species of *C. formicarius* and *E. postfasciatus* are reported to feed on the leaves and roots of carrots *Daucus carota* L. (Apiaceae) and radish *Raphanus sativus* L. (Brassicaceae) in Hawaii (Muruvanda *et al*., 1986).

The management and eradication of these weevils are vital for sweetpotato production in the Mariana Islands and also other parts of the world. Estimating pest densities is one of the best basic themes for management and eradication programs the accomplishment of which depends significantly on how precisely the densities are estimated (Ito and Yamamura, 2008). The general aim of the study to acquire reliable estimates in of weevil density was determined by densities estimated by the quadrat method in the Mariana Islands.

Materials and methods

Study sites

To obtain reliable estimates of the weevil's density, three to four sweetpotato fields were selected on the islands of Guam, Rota, Saipan and Tinian (Table 1). The sampling plans were developed according to the methodology described in Southwood (1978) and Pedigo and Buntin (1993). Two sets of samples, one in the dry and one in the wet season, were taken once the sweetpotato plants in each field were 80-90 days old. The field sites of the 14 sampling sites, determined with a 12-channel global positioning system (Garmin Corp., Taiwan), are listed in Table 1. Within each field site, three to four 0.4 acre plots were randomly chosen for estimation of the sweetpotato weevils (Table 1). Within each plot, one quadrat sample with the physical unit size of 1x1 m was taken. A wooden frame was placed horizontally above each quadrat, and all *C. formicarius*, *E. postfasciatus* and *D. tuberosus* adults inhabiting the vegetation underneath the frame or falling to the ground were identified and counted. Because of the uncertainties regarding the behavior of the beetles, the inspection of the canopy and the ground lasted 10 min.

Data analyses

To analyze field population densities per quadrat, a nested ANOVA model was applied to test for significant differences between fields within islands and between islands. This was done by using the GLIMMIX Procedure SAS Version 9.13 (SAS Institute Inc., 2009). Tukey HSD test was used to make multiple comparisons for significant differences between island population levels for the wet and the dry seasons. To compare the population levels on the islands, the percentage of *C. formicarius*, *E. postfasciatus* and *D. tuberosus* adults inhabiting each island in the dry and wet season was calculated. This was done by dis-regarding the weevils outside the sweetpotato fields and taking into account the size of sweetpotato fields on each island. To obtain island populations, the average density per quadrat was multiplied by the sweetpotato area on each island and translated into a percentage of occupation, also referred to as percentage of incidence, by means of dividing the island population by the combined number of weevils living on all islands.

Results

The results from the estimation of the population density indicated the population variation among four islands. During the dry season, 90% of population density of *C. formicarius* was noticed in Rota, which was followed by Saipan (75.5%), Tinian (58.5%) and Guam (54.5%) (Figure 2). A significant difference was observed ($P<0.05$) between population levels from Guam to Saipan, Tinian and Guam. However, there was no significant difference between population levels in Guam and Tinian. In the wet season, the population levels were recorded as 35.5% in Rota which was significantly higher than Guam (22.5%),

Table 1. Summary of study sites with geographical locations.

Island	Locality of fields	Geographical locations	No. of quadrat samples per field (n)
Guam	Latte Heights	13.26°N, 144.48°E, 79.9 m, a.s.l.	3
	Dededo	13.30°N, 144.51°E, 96.9 m, a.s.l.	4
	Mangilao	13.43°N, 144.80°E, 54.3 m, a.s.l.	3
	AES, Yigo	13.31°N, 144.52°E, 138.0 m, a.s.l.	4
Rota	Sinapalo	14.17°N, 145.24°E, 179.8 m, a.s.l.	4
	Gagani Farm	14.12°N, 145.17°E, 27.4 m, a.s.l.	3
	Mangloña Farm	14.13°N, 145.17°E, 175.0 m, a.s.l.	4
	Sinapalo-II	14.17°N, 145.24°E, 179.8 m, a.s.l.	4
Tinian	Tago Wells	14.97°N, 145.62°E, 9.4 m, a.s.l.	3
	Marpo Heights	14.98°N, 145.65°E, 17.7 m, a.s.l.	3
	Virginia Lizama	14.97°N, 145.63°E, 21.9 m, a.s.l.	4
Saipan	Garapan Area	15.20°N, 145.72°E, 14.3 m, a.s.l.	3
	Tanapag Zone	15.24°N, 145.76°E, 16.2 m, a.s.l.	3
	Capitol Hill	15.21°N, 145.75°E, 233.8 m, a.s.l.	4

a.s.l., above sea level.

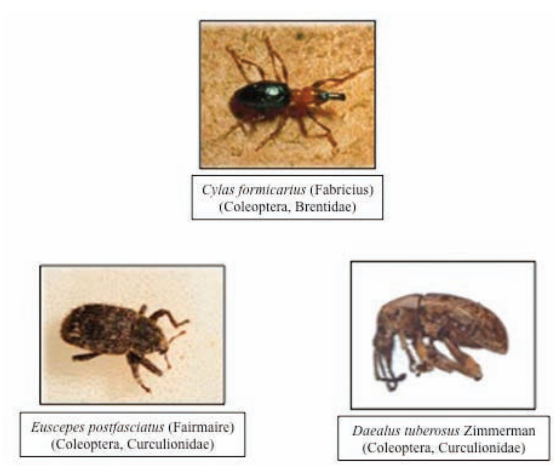

Figure 1. Sweetpotato weevils recorded in the Marianas Islands.

Saipan (26.0%) and Tinian (13.5%). No incidence of *E. postfasciatus* was observed on Guam (Figure 3). In the dry season, 45.0% of *E. postfasciatus* was recorded in Rota which was significantly (P<0.05) higher than in Saipan (26.5%) and Tinian (2.5%). In the wet season, 22.0% of the population was observed in Rota which is significantly higher than in Saipan (12.0%) and Tinian (5.0%). No prevalence of *D. tuberosus* was noted in Guam (Figure 4). In the dry season, a significantly higher (P<0.01) population (25.0%) of *D. tuberosus* was observed in Rota than in Saipan (12.5%) and Tinian (7.5%). Similar population trends were observed in the wet season. Significantly higher population was observed in Rota (12.5%), which was followed by Saipan (5.5%) and Tinian (2.5%). Overall, there was a significant difference (P< 0.001) between population levels in the dry season and the wet season among the four islands.

Discussion

According to Chalfont *et al*. (1990), no sampling methods have been developed. Also, a reliable sampling method for *C. formicarius* is not available. There are several methods for sampling insect populations in agricultural crops, including visual assessment, beat cloth, sweep net and D-vac sampling that have been used around the world (Kogan and Pitre, 1980). In the present study, visual assessment was used for sampling because of the uncertainties regarding the nature of the pest species. Weevil populations are thickly clumped in sweetpotato fields (Jansson *et al*., 1990). Also, between 82% and 91% of the total population is below the surface of the soil, and between 78% and 89% of the total population is found in the area extending from 10 cm above the ground to 15 cm below the ground (Jansson *et al*., 1990). Therefore, reliable estimates of weevil population may be obtained by sampling the plant (Chalfont *et al*., 1990) as carried out in the present study. Nevertheless, all these techniques can be viewed as being relative sampling techniques. This will help to plan their use in decision making against thresholds based on absolute population densities in order to calibrate the relative sampling technique to the absolute population in the field (Duffield *et al*., 2005). Likewise, Hanson (1967) suggested that the population density of animals from total counts on sample plots requires the variance of the counts to be kept fairly low. As the plot size is increased, it reduces the variance due to clumping, but at the same time, the increase in the size of individual plots often leads to a reduction in the number of plots. Based on this theory, the number of counts taken from the present study is appropriate to count the population from the field. Although nearly 30 alternative wild hosts have been recorded as sweetpotato weevil hosts (Hill, 1983), the weevil population prefers and attacks primarily *I. batatas*. Moreover, the islands do not have all the alternative hosts. Therefore, insect densities outside sweetpotato fields are not required for calculating a *weevil incidence* for each island.

The present results indicate a higher incidence of *C. formicarius* in all the four islands, particularly in Rota where it reached 90% population level in the dry season. This indicates the severity of the pest and is a warning to growers. In fact, if the necessary control methods are not adopted, the whole crop could be lost. There have been previous reports of the damage caused by this weevil. According to Sutherland (1986) and Chiranjeevi *et al*. (2003), *C. formicaries* can cause considerable damage, with reports of losses ranging from 5% to 100%. This weevil infestation ranges from 20% to 50% on many growing farms and can even reach 100% in some seasons and varieties (Ames *et al*., 1996). In Louisiana, losses from *C. formicarius* range from 5 to 97% in areas where the weevil can be found (Cockerham *et al*., 1954).

According to Messenger (1954), *E. postfasciatus* is confined to the tropical areas of the western hemisphere, mainly around the

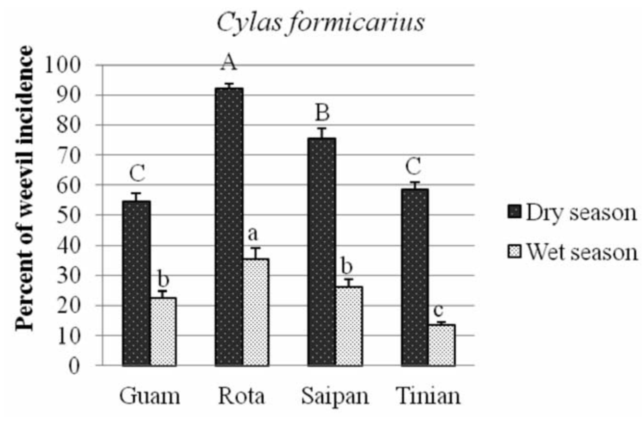

Figure 2. Mean percentage of incidence (±SEM, standard error mean) of *Cylas formicarius* on sweetpotato fields in the Mariana Islands. Bars with different letters are significantly different between population levels (nested ANOVA, Tukey HSD, P<0.05).

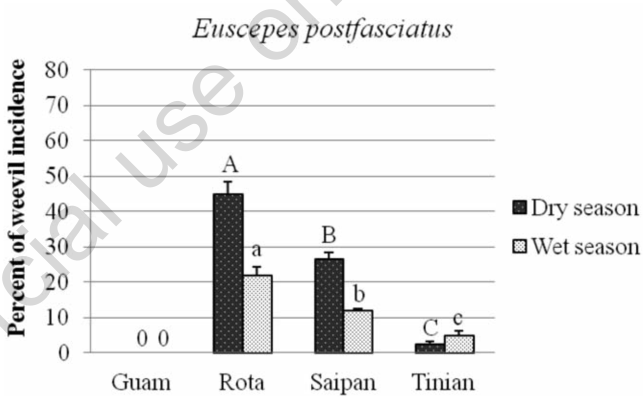

Figure 3. Mean percentage of incidence (±SEM, standard error mean) of *Euscepes postfasciatus* on sweetpotato fields in the Mariana Islands. Bars with different letters are significantly different between population levels (nested ANOVA using Poisson's model, Tukey HSD, P<0.05).

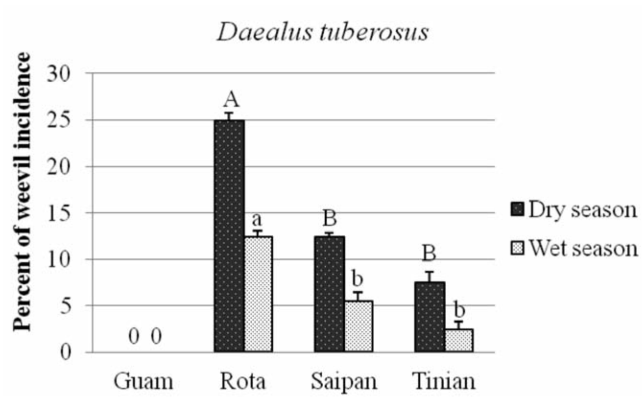

Figure 4. Mean percentage of incidence (± SEM, standard error mean) of *Daealus tuberosus* on sweetpotato fields in the Mariana Islands. Bars with different letters are significantly different between population levels (nested ANOVA using Poisson's model, Tukey HSD, P<0.05).

Caribbean. It is also found in Hawaii, Fiji, Tonga and on Okinawa island in Japan. The results from the present study indicated that *E. postfasciatus* is the second most destructive pest of sweetpotatoes in the Mariana Islands. This weevil was recorded for the first time in Rota during 1946 (Zimmerman, 1948). It is believed that this weevil was accidentally introduced into Okinawa from Hawaii or Saipan (Kohama, 1990). In Hawaii, a conservative estimate by Sherman and Tamashiro (1954) of the loss due to this pest was reported to be from 10% to 20% of the crop. This weevil is distributed throughout the Okinawa Islands in Japan, where it heavily infests sweetpotatoes (Yasiuda and Kohama, 1990). Although *D. tuberosus* was first recorded on sweetpotatoes in 1946 on Guam (Zimmerman, 1948), this species was not found or did not cause damage to sweetpotatos in Guam in the present study. However, the present sampling studies have shown *D. tuberosus* to be the third most destructive pest in Rota, Saipan and Tinian. This species was also first recorded in 1946 on Rota (Zimmerman, 1948) and, since there was no quarantine regulation within these islands, spread to Saipan and Tinian.

In conclusion, the present sampling study revealed that *C. formicarius* is the most destructive pest on sweetpotato in all the islands. This was followed by *E. postfasciatus* and *D. tuberosus* whichcaused damage to sweetpotatoes in the Commonwealth of Northern Mariana Islands (CNMI). Therefore, the management or eradication of these weevil pests is urgently required to save sweetpotatoes in the Mariana Islands.

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