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Feeding Behavior of Sweet Potato Weevil, *Cylas formicarius* (Fabricius) (Coleoptera: Brentidae) on Three Sweet Potato, *Ipomoea batatas* L. Cultivars Grown in Tarlac, Philippines

Jerah Mystica B. Novenario[1,*] and Flor A. Ceballo-Alcantara[2]

[1]College of Agriculture Systems and Technology Pampanga State Agricultural University, PAC, Magalang, Pampanga 2011 Philippines
[2]Institute of Weed Science, Entomology and Plant Pathology, College of Agriculture and Food Science, University of the Philippines Los Baños, College, Laguna

[*]Author for correspondence: E-mail: jerahmystica_novenario@psau.edu.ph

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Sweet potato is grown in tropical countries for its edible tubers, which have become an essential food source. It is usually propagated through vine-cutting, which can be obtained from harvested plants or nurseries intended for cutting production only. The recurrent use of vines may cause increased weevil infestation. The crop is known to be infested with insect pests. More importantly, the sweet potato weevil, *Cylas formicarius*, targets the tubers, thus, causing the economic losses. Sweet potato farmers in Tarlac claim that only one sweet potato cultivar is being attacked by *C. formicarius*, however, it was found in this experiment that the feeding and feeding behavior of the weevil were not affected by the cultivar provided, such that there is no significant differences observed in the average amount of tubers consumed by both male and female feeding time and degree of damage.

Keywords: *Cylas formicarius*, feeding behavior, insect pest, sweet potato, sweet potato weevil

INTRODUCTION

Sweet potato, *Ipomoea batatas* L., is one of the most significant crops in the world, although numerous pests limit its yield (Smith et al. 2013). The sweet potato weevil, *Cylas formicarius* Fabr. (Ray and Ravi 2005), and the West Indian sweet potato weevil, *Euscepes postfaciatus* Fairm. (Limon 2017) are two major insect pests infesting sweet potato tubers in the tropical and subtropical countries. Larvae and adults of both insect species tend to attack the roots and vines of sweet potato tubers. These weevils are the most severely damaging pests of sweet potato around the world. They cause damage to the crop in the field and in storage and is of particular quarantine importance (Capinera 2021). Different subspecies of the pest occur in different areas of the world; however, their mode of infestation is almost the same (Capinera 2001). As cited by Okada et al. (2014), the weevils have distinct modes of damage such that physical injury is inflicted when the weevils feed, therefore creating problems on the surface and flesh. Liao et al. (2020) reported that tuber infestation of sweet potato weevils results in the induced production of secondary metabolites that eventually reduce tuber quality and marketability. In the Philippines, the yield of sweet potato is reduced by up to 50% due to damage by *C. formicarius* (Gapasin 1989).

With the development of new varieties, even for single-crop plants, the insect-plant relationship is likely altered, and the amount of damage due to insect attacks may vary. The response of phytophagous insects on different varieties is affected by the interplay of the varietal plant quality and the innate behavior of the insect pest itself. This may lead to one variety having less damage than the other variety of the same crop. Variety with insect resistance properties suppresses insect pest damage, and plants can repair, grow, and reproduce. Additionally, plant varietal quality that suppresses insect response to feed may result in a longer developmental period or affect fecundity (Wiseman 1996; Shahout et al. 2011; Smith 2021). Resistant cultivars often possess distinct chemical compositions, including secondary metabolites and defensive compounds, which deter *Cylas formicarius*. These defensive compounds alter the flavor and nutritional value of sweet potato tubers (Stevenson et al. 2009; Mugisa et al. 2022). Some cultivars also possess morphological attributes that alter the feeding preference of weevils (Parr et al. 2016).

Knowledge of the insect-plant interaction among cultivars is vital for the correct use of resistant cultivars in an integrated pest management system. Among the several sweet potato varieties in Tarlac, three varieties turned out to be appealing to local farmers, who claimed that a heavy infestation of *C. formicarius* was observed in the cultivar 'Super Bureau' (Melvin Anucension, personal communication with author, February 2020). They further mentioned that the weevil was observed to be seldom present in other cultivars. Local studies conducted on sweet potato are few and mostly focus on breeding and production. There is also a lack of research done on the local population of *C. formicarius*; more data is needed to help understand how this insect affects the crop, which will eventually contribute to the management of this pest. Thus, this study was conducted to determine the effect of three varieties of sweet potato on the feeding behavior of the weevil. Specifically, this research aimed to investigate the following: a) activity pattern; b) feeding period; c) duration of feeding; and d) degree of damage of the weevil on three sweet potato cultivars.

MATERIALS AND METHODS

Sweet Potato Cultivars as Test Plants

Three sweet potato cultivars commonly grown by farmers in the province of Tarlac were used in the study: 'Inubi', 'Super Bureau', and 'Bureau'. These are among the various cultivars planted in the province, which contributed to almost 71.50% of the total sweet potato production in Central Luzon in 2022 (PSA 2023).

'Inubi' is generally characterized as having purple skin with white tuber flesh and streaks of purplish lines. It is usually harvested at 75 – 90 d after transplanting. 'Super Bureau', on the other hand, has a reddish-purple skin color and white flesh. This cultivar is harvested at 90 – 120 d after planting of cuttings. Likewise, 'Bureau' has a slightly reddish-purple skin color and yellowish or creamy white flesh. Tubers are also harvested at 90 – 120 d after planting.

These cultivars also share some similar plant characteristics. 'Inubi' and 'Bureau' have green to dark green foliage, while 'Super Bureau' has greenish-purple leaves. 'Bureau' and 'Super Bureau' are spreading types, while 'Inubi' is slightly erect.

Culture of Sweet Potato Weevil

The insect culture and rearing based on the methods done by Adom et al. (2018) is shown in Fig. 1. A colony of sweet potato weevil, *C. formicarius*, was established at the BioCon Laboratory of the College of Agriculture Systems and Technology, Pampanga State Agricultural University from infested tubers collected from sweet potato fields in Barangay Balutu, Concepcion, Tarlac (with coordinates 15.3024, 120.6946; 15° 18' North, 120° 42' East). The tubers were incubated in a rectangular plastic container (17 x 11 x 6.5 cm) fitted with a mesh cover at the top to allow ventilation. Paper towels were placed at the bottom to absorb excessive moisture from transpiration and stored tubers' putrefaction. Upon emergence, male and female adults were removed from the containers and were kept in a separate rectangular plastic container where they were provided with healthy, disease-free tubers for infestation. The male and female sweet potato weevils are morphologically similar in body appearance except for the terminal antennal segment; the female weevil has an ovoid terminal segment, while the male has a cylindrical terminal antennal segment. The infested tubers were removed and replaced every week, and then placed in incubation boxes to allow further adult emergence.

Activity Patterns of the Adult Weevils

One pair of adult male and female weevils was placed inside a transparent plastic container (14-cm diameter, 8.5-cm depth) which served as an observation arena. One

Fig. 1. Sweet potato tuber infested with *Cylas formicarius* Fabr.

sweet potato tuber was exposed to the weevil at 1800 to 0500 h to determine the activity patterns of both the male and female adult weevils. This was done to establish the approximate time when feeding, mating, and ovipositional activities are performed within the 12-h dark period (night) as the insect is nocturnal. The pair of weevils were observed for 30 min at the top of the hour to record the activities performed by the insect. Another pair of adult weevils was observed following the same procedure to complete the 12-h dark period. The activities were plotted to establish the different activities performed by the insect and the peak and inclusive time these activities are likely observed. Temperature during the observation ranged between 28°C – 31°C.

Feeding Behavior of Adult Weevils and Larvae

A preliminary setup was conducted to ascertain the time of day when feeding activities were at peak, which was mostly observed at night between 2000 – 2100 h.

After determining precise periods of the night for these activities, observations relevant to feeding were done to record the length of time spent feeding and the amount of tuber consumed within 24 h of exposure.

a) ***Adult feeding consumption.*** The experiment was conducted by introducing one adult weevil into the observation arena (14-cm diameter, 8.5-cm depth). One tuber slice of the sweet potato variety at a time was provided to the adult weevil (no choice test). Sweet potato tubers were cut into cubes and weighed before being placed inside the observation arena to serve as food for the adult weevil. The adult weevil was allowed to feed for 24 h after which the tuber cubes were taken out and weighed to measure the amount of tuber consumed by the lone weevil. The difference in the pre-exposure and post-exposure weights was considered as the amount of food consumed by the adult. The number of adults tested was limited to five individuals for this test and all the other tests because of the difficulty of procurement of supplies, mobility, and access within the locality and into the laboratory due to strict regulations related to the lockdown brought about by the Covid pandemic of 2020.

A similar setup described above was conducted using the tubers of the two other sweet potato varieties and a new set of adult weevils. The total amount of food consumed by the weevils was measured and converted to the Relative Consumption Rate Index (RCRI) index. The RCRI of the weevils was calculated as weight consumed per unit initial weight of the insect using the RCRI index as suggested by Farrar et al. (1989) and as shown below:

$$RCRI = I / (B1)\ T$$

b) ***Larval feeding consumption.*** Feeding consumption by the larva was conducted using the third instar stage instead of the first instar to minimize accidental mortality during larval extraction and handling. One larva was placed inside a transparent plastic container (14-cm diameter, 8.5-cm depth) with a lid. The surface of a sweet potato tuber cut was carefully scraped where the larva was placed and covered to make a tunnel impression for the larva. One tuber slice of the sweet potato variety at a time was provided to the larvae to make a total of five larvae (no choice test). Sweet potato tubers were cut into cubes and weighed before being placed inside the observation arena to serve as food for the third instar larvae. The larva was allowed to feed for 24 h after which the tuber cubes were taken out and weighed to measure the amount of tuber consumed by the lone larva. The difference in the pre-exposure and post-exposure weights was considered as the amount of food consumed by the larva.

Damage Assessment

Tubers of the three cultivars were sliced into 3-mm-thick segments and exposed to the weevils. Damage caused by the sweet potato weevil was assessed based on the degree of tuber damage after exposure to the weevil for 24 h using the photographic guide (Fig. 2) by Okada et al. (2019). The degree of damage was converted into scores ranging from 1, considered as no damage, and 5, as severely damaged, resulting in five ranks.

Statistical Design

All data (amount of tubers consumed, average feeding time, and damage scores) were analyzed using one-way ANOVA with Least Significant Difference (LSD) as post-hoc thru the Statistical Tool for Agricultural Research (STAR) packages. In all tests, the significance level was 0.05.

RESULTS AND DISCUSSION

Activity Pattern of Adult *C. formicarius*

The activity pattern of adult *C. formicarius* weevils during the 12-h dark period observation (scotophase) is shown in Fig. 2. At the onset of the observation, both male and female weevils exhibited death-faking behaviors. Death-faking behavior is becoming immobile or "playing dead" when external threats are sensed (Miyatake 2021). It is expected for this species to have a survival instinct when external movements and interventions are sensed. Putting them together in an observation arena, an external intervention, resulted in a death-faking behavior response. The death-faking behavior lasted for an average of 37 min, after which the insects were observed

Table 1. Mean ±SEM amount of sweet potato tuber consumed per larvae and adult weevil per day and the average time spent for feeding regardless of the sex of the weevil inside the observation arena.

Sweet Potato Variety	Food Consumed per Day (mg)			Feeding Time of Adults (min)
	Female	Male	Larvae	
Inubi	0.096 ± 0.001	0.129 ± 0.002	0.062 ± 0.001	44.0 ± 1.301
Super Bureau	0.092 ± 0.001	0.134 ± 0.002	0.064 ± 0.002	43.4 ± 1.075
Bureau	0.095 ± 0.001	0.113 ± 0.004	0.065 ± 0.002	45.4 ± 0.819

to roam around the container in no particular direction. Male weevils were observed to roam along the arena's walls for an average of 45 min while females walked closer to the sweet potato tuber for an average of 1 h. This behavior differently exhibited by the male and female weevils may be related to the volatiles secreted by different parts of the sweet potato plant. Smith (2006) discussed that female sweet potato weevils are attracted by the volatiles secreted from the leaves and storage roots, while males are attracted by leaf volatiles.

The male weevil started boring at the top of the tuber around 2000 h (8:52 PM). Feeding was presumed to have been made when a hole was created in the tuber. The male stopped feeding after 53 min and walked fast around the observation arena, making a few mounting attempts on the female weevil. Mating attempts lasted for an average of 45 s. The male weevil stayed beneath the tuber afterward.

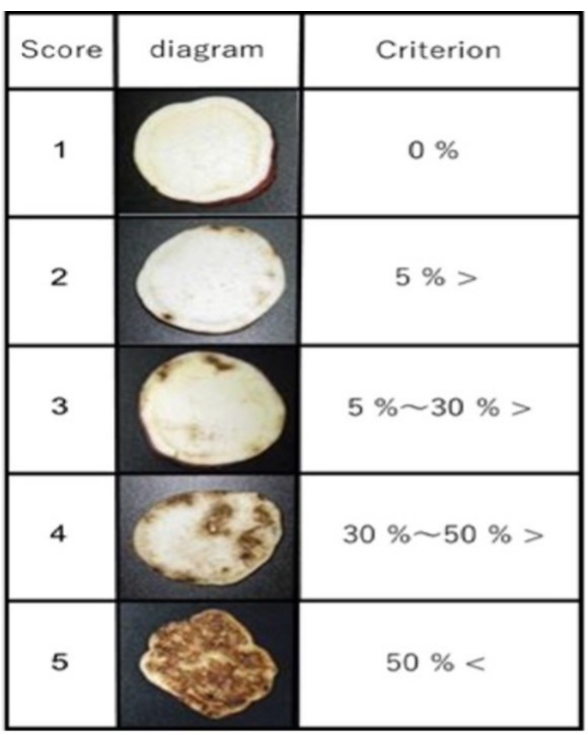

Fig. 2. The level of tuber damage by the weevil and the corresponding score according to the maximum damaged area on the cross-section of the tuber (Okada et al. 2019).

Unlike the male weevil, the female weevil did not move much upon release inside the arena and stayed in its place for almost 4 h—from 1800 h until 2200 h. However, at 2230 h, the female started boring its snout on the tuber, and the snout was retracted several times. The female weevil's feeding time was recorded for 57 min on average.

Like the male, the female weevil was mobile and moved much quicker after feeding.

Feeding Behavior of *Cylas formicarius*

a) Adult weevils

The average amount of sweet potato tubers consumed by female and male adults of *C. formicarius* daily is shown in Table 1. No significant differences were observed in the average amount of sweet potato tubers consumed by both male (F = 0.86; df = 2; P < 0.45) and female (F = 2.71; df = 2; P < 0.11) adult *C. formicarius* exposed on three sweet potato varieties.

These results are similar to the observations of Nottingham et al. (1987) who compared the feeding preferences of adult weevils on the inner core of three sweet potato cultivars. They noted that no differences in feeding were exhibited by weevils among the root inner cores of sweet potato.

In terms of average tuber consumption of larvae, no significant differences (F = 0.66; df = 2; P < 054) were observed in the amount of sweet potato tubers consumed by *C. formicarius* larvae per day. Thus, no varietal preference for the tuber as larval food was manifested. The larvae's average length of feeding time was not measured since the larvae were covered with sweet potato flesh, and excavating the tuber was too risky. Aside from the fact that they were located within the tubers, the larvae were soft-bodied and delicate—excavating the tuber might cause maceration of the larvae.

Adult Feeding Duration

The average feeding time of adult *C. formicarius* is shown in Table 1. No significant differences (F = 0.9; df = 2; P < 0.43) were observed in the feeding time spent by the adult weevils concerning the sweet potato variety provided. However, feeding activity peaked at 2000 h

Table 2. The average damage scores of sweet potato tubers after 24-h exposure to adult weevil. The assessment was made using the scale of Okada et al. 2019.

Sweetpotato Variety	Damage Score
Inubi	3.27 ± 0.081
Super Bureau	2.20 ± 0.068
Bureau	3.40 ± 0.125

regardless of the sweet potato variety they were exposed to. Additionally, weevils may display scattered and brief feeding bouts during the day, but a longer feeding bout was expected at night, lasting for less than an hour.

Damage Assessment Due to Adult Feeding

Damage scores due to feeding by adult weevils on the three sweet potato varieties with no choice test were not significantly different (F = 1.64; df = 2; P < 0.23) from each other (Table 2). The damage score on 'Super Bureau' was lower compared to the other two varieties offered to the weevils. However, the degrees of damage on varieties 'Bureau' and 'Inubi' were comparable with each other, which were higher than the 'Super Bureau'. Varieties 'Bureau' and 'Inubi' appear to be preferred by the weevils.

However, further investigation using a choice test is needed to determine varietal preferences for larval or adult food and as an oviposition medium. Additionally, the damage scores proposed by Okada et al. (2019) on sweet potato tubers may be modified to make the increments similar to what is being used in the damage assessment of other crops using scores such as 0, 1, 3, 5, and 7 with 0 as no damage and 7 as severely damaged.

Under the regular farming practice, one variety of sweet potato is usually planted over a given area (simulating a no-choice test) where the adult weevil has only one food source available, and the potential damage can be assessed.

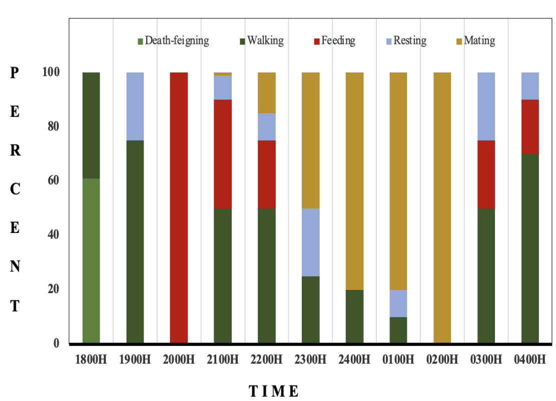

Fig. 3. Activity pattern of adult male and female *Cylas formicarius* Fabr. during the 12-h dark period observation.

A closer investigation of the damage on the tuber exposed to the weevil appears to be similar across a variety with an exposure time of 24 h (Fig. 3). Further investigation is recommended to extend the time and continue observation until 72 h for a more reliable and stronger data set.

CONCLUSION

The results of the experiment showed that the feeding behavior of *Cylas formicarius* Fabr. is not affected by the cultivar where they are exposed. This implies that the weevils may be able to inflict similar injuries to sweet potato tubers. However, further investigation using a choice test may be conducted to validate the results of the experiment. Additionally, the exposure time may be extended from 24 to 72 h to fully capture the weevil's response to the cultivars. This will provide a more robust data set and draw a more reliable conclusion.

On the other hand, the claims of sweet potato farmers in Tarlac wherein variety 'Super Bureau' is heavily infested by *C. formicarius* as compared to other varieties may have resulted from a combination of environmental, biological, and observational factors. Sweet potato weevils exhibit cryptic behavior by hiding in stems, vines, or the soil during the day. Their small size and their ability to burrow into plant tissues also make them challenging to detect visually. Some farmers may not notice the damage until it becomes severe, resulting in reduced yield. To improve the detection of weevils in sweet potato fields, farmers may benefit from adopting integrated pest management strategies including regular field monitoring, use of pheromone traps, training programs for pest identification, and timely application of appropriate control measures. Early detection is crucial to minimize the impact of weevil infestations on sweet potato crops.

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