The Distribution and Biological Observations of the Mango Weevil, *Cryptorhynchus mangiferae* (Coleoptera: Curculionidae), in Hawaii[1]

JAMES D. HANSEN[2,3], JOHN W. ARMSTRONG[2], and STEVEN A. BROWN[2]

ABSTRACT

The distribution and life history of the mango weevil, *Cryptorhynchus mangiferae* (Fabricius) (Coleoptera: Curculionidae), was studied in Hawaii. The weevil was found on all major islands, but its distribution was not related to location on island, host plant density, cultivar, or other environmental parameters. Populations were sampled in a mango orchard at biweekly intervals during the fruiting season. No differences were found in infestation rates among fruit in different vertical zones in the canopy. Head capsule width data suggested that there were more than five larval instars. Young larvae were first collected in mid-April while pupae and adults were first found at the end of May. More than one weevil can successfully develop in a seed. In the field, adults appeared to randomly select oviposition sites.

The mango weevil, *Cryptorhynchus mangiferae* (Fabricius) (Coleoptera: Curculionidae), is an important pest of Hawaiian mangoes because infested fruit cannot be shipped to the United States mainland (Seo et al. 1974). This insect is found throughout the range of mangoes, its only known host, except for areas throughout North and South America (Balock and Kozuma 1964, Shukla and Tandon 1985). The mango weevil was first discovered in Hawaii in 1905 (Van Dine 1906).

The life cycle of the mango weevil was briefly described by Rutherford (1914) and Jarvis (1946). Eggs are laid on the outside of developing fruit. Following eclosion, the larvae burrow through the flesh to the young seed which they penetrate. The weevil completes its development within the maturing seed. Ovipositional behavior, larval morphology, and adult diapause were discussed by Subramanyam (1925) and Shukla and Tandon (1985). In Hawaii, Swezey (1922, 1931, 1935, 1943a, 1943b) provided anecdotal observations on mango weevil infestations. More importantly, Balock and Kozuma (1964) elaborated on the biology of the mango weevil in Hawaii by quantifying their research.

---

[1]Mention of a proprietary product does not constitute an endorsement for its use by USDA-ARS.

[2]Tropical Fruit & Vegetable Research Laboratory, Agricultural Research Service, U.S. Department of Agriculture, P.O. Box 4459, Hilo, Hawaii 96720.

[3]Current address: Beaumont Agricultural Research Center, University of Hawaii, 461 W. Lanikaula St., Hilo, Hawaii 96720.

Nevertheless, despite published information, many aspects of mango weevil biology in Hawaii were unknown. Obscure areas included its distribution within the state, host plant relationships, seasonal population fluctuations in the field during development, habitat selection, and various behavioral characteristics. The objectives of our study were to clarify these components of the biology of the mango weevil in Hawaii.

MATERIALS AND METHODS

Distribution

All major islands in Hawaii except Lanai were surveyed for the mango weevil during the summer of 1986, when mango trees were bearing fruit. Most sampled fruits weighed more than 100 g, but smaller fruits were taken when necessary. Fruits were collected from established orchards, yards of homes and public establishments (e.g., hotels, churches, etc.), and from "wild" or volunteer trees. Fruit sample sizes varied with site, from a minimum of 5 to a maximum of 127, with a sample size of 10 as typical. Locations with low initial infestation rates (<25%) were resampled when possible. Samples were categorized by cultivars when known. Sites were selected to represent a wide range of geographical distribution and environmental diversity.

Mango weevil infestations were determined by dissecting the fruit in the laboratory, observing if weevils were present, and recording the life stages. All stages collected were stored in 70% ethanol. Fruit size was measured by weight.

Population Sampling

To determine seasonal population levels, a study site was established in a commercial orchard in Kalapana, Hawaii Co., Hawaii. From a pool of eleven mango trees with fruit at the same stage of ripeness, five randomly selected trees were sampled biweekly beginning April 2. The canopy of each tree was divided into three vertical zones (top, middle, bottom) and four directional quadrants (north, east, south, west). For each sampled tree, six fruits were collected from each of the lower two zones and in the same randomly selected quadrant. For the June 11 sample, five fruits per quadrant from each of six trees were obtained. By the second week in July, all the fruit on the trees had been removed, so this sample consisted of twelve fallen fruit and bare seeds collected under each of the five randomly selected trees.

In the laboratory, each fruit was weighed, then dissected to determine number and life stages of the mango weevil. Weevil specimens were preserved in 70% ethanol. Larval head capsule widths were measured by using a stereomicroscope with an ocular micrometer. First and last instars were identified by using the description given by Balock and Kozuma (1964).

Data Analysis

Statistical tests (e.g., Student's *t* test, goodness of fit of the Poisson distribution, chi-square test) were done following the procedures of Zar (1974). Computations were done on a Hewlett- Packard HP-11C calculator.

RESULTS

Distribution

The mango weevil survey was based on the distribution of the mango trees. Mangoes generally grow at low elevations along the periphery of each island. Trees which bore fruit were more common in the drier parts of each island. Very few trees were found at elevations above 300 m in the interior. Mango trees were scarce in western Molokai and northwestern Hawaii. Northeastern Maui and northern Hawaii (high rainfall areas) had trees, but no fruit.

Mango weevils were found on all islands surveyed (Table 1, Fig. 1). The highest infestation rate per island (51.7% of fruit) was from Kauai, whereas Maui had the lowest (20.5%). There was no consistent level of infestation in samples from sites in the same general area or with similar environmental characteristics. For example, samples from two sites in Na'alehu (Hawaii Co.) were 0% and 90%, and, on Oahu, Niu Valley and Aina Haina Valley, which are less than 2 km apart, had infestation rates of 100% and 0%, respectively. Furthermore, the distribution of the mango weevil was not related to geographical location on the islands. No other insects were found within the seeds except in those of deteriorating fruit, and in an occasional otherwise sound mango.

The largest collections were from the orchards, yet these generally had low infestation rates. The most productive commercial orchard in the State (Kihei, Maui Co.), was sampled twice (May 21, n = 95 fruit, 1.1% infestation; July 21, n = 60 fruit, 0% infestation). On Oahu, an orchard at Waianae had a rate of 23.3% (n = 60 fruit), and, at the University of Hawaii Wai-

TABLE 1. Number and frequency of larvae of the mango weevil, *Cryptorhynchus mangiferae*, in fruit from island survey collections.

Island	No. Larvae/Fruit[a]						
	0	1	2	3	4	5	Total
Maui	167(80)	34(16)	7(3)	1(0)	1(0)	0(0)	210
Molokai	61(65)	31(33)	2(2)	0(0)	0(0)	0(0)	94
Kauai	73(48)	66(44)	12(8)	0(0)	0(0)	0(0)	151
Hawaii	99(58)	50(29)	18(10)	4(2)	1(1)	0(0)	172
Oahu #1	56(43)	57(45)	11(9)	4(3)	0(0)	0(0)	128
Oahu #2	126(73)	35(20)	12(7)	0(0)	0(0)	0(0)	173
Total	582(63)	273(29)	62(7)	9(1)	2(0)	0(0)	928

[a]Numbers in parentheses express frequency as per cent.

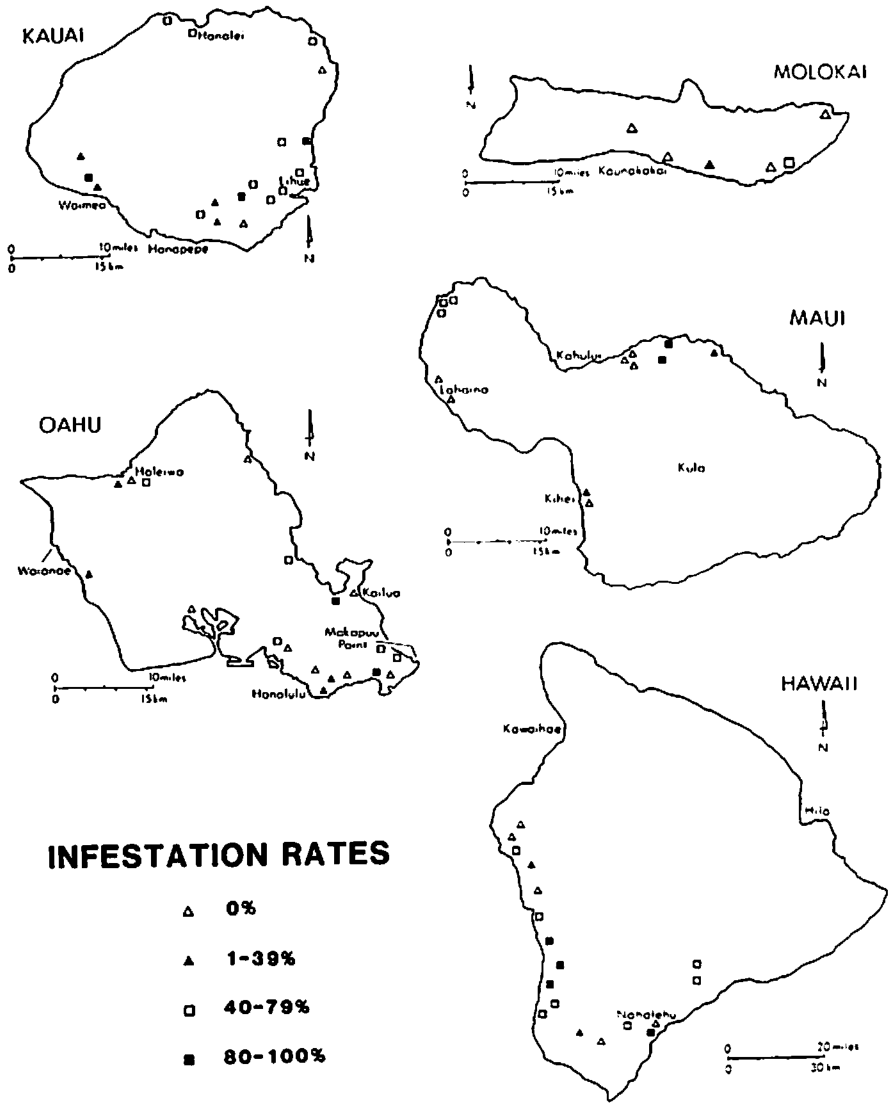

FIGURE 1. Distribution and infestation rates of the mango weevil, *Cryptorhynchus mangiferae*, on the five major islands of Hawaii.

manalo Agricultural Experiment Station, the rate was 58.3% (n = 127 fruit). An orchard at Mapulehu on Molokai had the highest infestation rate at 67.5% (n = 40 fruit).

Mangoes from these orchards were separated by cultivar when possible. These included: 'Erwin', 'Golden Glow', 'Haden', 'Kent', 'Kiett', 'Mapalaho', and 'Waianae Beauty' at Waianae (Oahu Co.); 'Ah Ping', 'Carabao', 'Edward', 'Fairchild', 'Gouveia', 'Haden', 'Harder', 'Joe Welch', 'Momi K', 'Paris', 'Pope', 'St. Francis', and 'Zill' at the Waimanalo orchard. No significant differences were found in the infestation rates among these cultivars.

Population Sampling

After paired Student's *t* tests showed no significant difference in infestation rates between fruits from the bottom and middle zones, these data were pooled.

No larvae were found in the first collection (April 2), then only first instars in the next sample (April 16) (Fig. 2). Fruit weight from the first collection ($\bar{X} \pm SE = 82.2 \pm 4.2$ gm) was about half that of the second ($\bar{X} \pm SE = 182.4 \pm 8.1$ gm).

The May 14 collection contained the last fruit with first instar larvae, the first samples with mature larvae, and the first occurrence of tunnels with

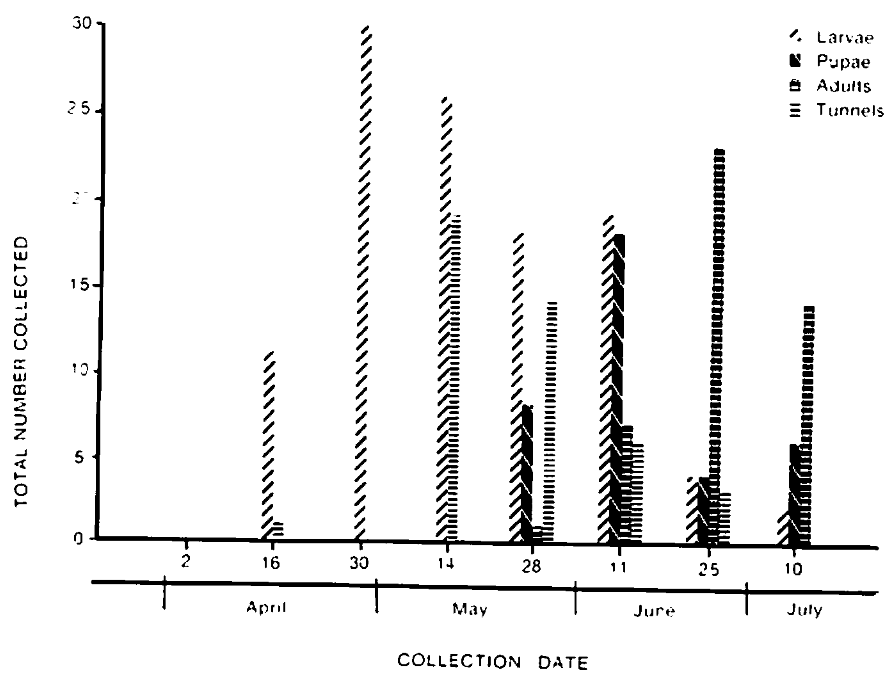

FIGURE 2. Biweekly population data of life stages of the mango weevil, *Cryptorhynchus mangiferae*, during 1986 from a commercial orchard in Kalapana, Hawaii.

frass but with no larvae in the seeds. The first pupae and adults were in the collection of May 28. Maximum population was recorded on June 11, then population levels declined in the last two collections. Life stages recovered from fruit flesh were two larvae (June 25) and a pupa (July 10). No parasites of the mango weevil were recovered.

In the last collection, where the samples were from the ground, fruit flesh had been consumed by mongooses and rodents while seeds were attacked by other beetles and moth larvae. Some seeds with mango weevil larvae germinated. In other seeds, adult weevils had chewed exit holes and escaped. On August 7, several adults were collected on bark of mango trees. In an August 26th seed survey, 36 of 50 randomly selected seeds collected on the ground had exit holes, and 11 of 55 seeds without exit holes contained adult weevils.

Larval head capsule widths ranged from 0.1 to 1.5 mm with the greatest frequency between 1.2 and 1.4 mm (Fig. 3). When the head capsule width data from the island survey collections were included, a secondary peak between 0.7 and 0.9 was evident.

The survey data (Table 1) were used to determine if oviposition was random. Data on the number of insects inside a seed (0, 1, 2, or 3 and more) were tested for goodness of fit with a Poisson distribution by chi-square. No

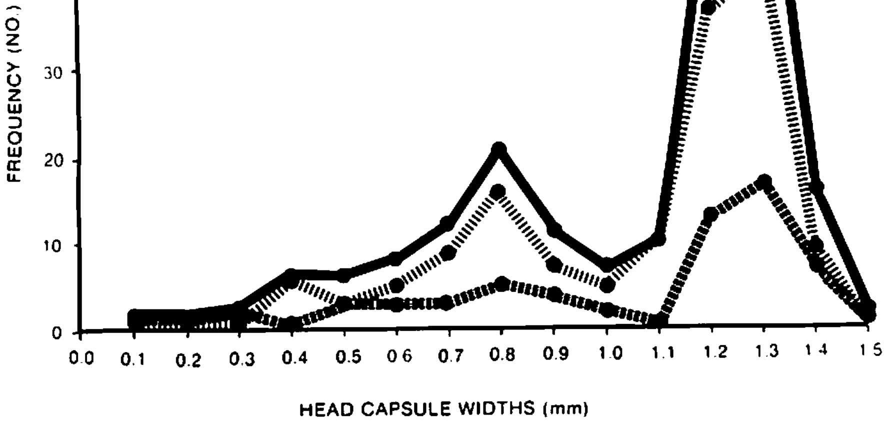

FIGURE 3. Frequency distributions of larval head capsule width measurements of the mango weevil, *Cryptorhynchus mangiferae*, collected from the life table study conducted at a commercial orchard in Kalapana, Hawaii, and the mango weevil survey of the major islands of Hawaii.

significant differences were found between observed and expected values ($x^2 = 2.26$, df = 2), indicating that oviposition was random.

DISCUSSION

Distribution

Localized areas with high infestation rates were found on each of the islands surveyed. Yet, nearby sites often had few or no mango weevils. The factors causing this mosaic distribution are unknown. Host plant density, mango cultivar, and geographical location on island were discounted. Perhaps distribution may be related to microhabitat characteristics.

The established mango orchards had relatively lower infestation levels than other sites, even though these orchards were not managed for mango weevil control. None of the orchards used sanitation practices or insecticide regimes against the mango weevil. Application of other chemicals was undocumented. Perhaps the orchards were fortuitously located in areas with low indigenous mango weevil populations. Conversely, our data suggested that wild and backyard trees are continuous sources of the mango weevil.

The infestation rates among the cultivars collected from the orchards were not significantly different. Balock and Kozuma (1964) found that 93% of the wild common mangoes they sampled contained mango weevils, 53% of the wild 'Chinese', 37% of 'Pirie', and 22% of 'Haden'. They also indicated that cultivars, such as 'Itamaraca', which have hard seed coats in very young fruits may be poor hosts for the mango weevil.

Population Sampling

The oviposition period at the Kalapana orchard was relatively short, occurring within April. Subramanyam (1925) in India found that mango weevils in the field oviposited over a three-week period. Balock and Kozuma (1964) recorded that oviposition in the laboratory may last 90 days. Shukla and Tandon (1985), also in India, reported that oviposition took less than 8 days beginning when the fruits were marble size. As the fruits matured the seed covering became hard, and the first instars could not penetrate the endocarp.

The duration of the larval period may be influenced by climate, location, host cultivar, and non-biotic site characteristics (e.g., soil chemistry, humidity, etc.). Shukla and Tandon (1985) reported that larvae averaged about a month to develop. Balock and Kozuma (1964) calculated the larval period in Hawaii at 22 days. In our study, the larval period was considerably longer (Fig. 2). Assuming that oviposition was completed by the end of April, larvae were still collected in the second week of July. This indicates that some larvae were ten weeks old.

The pupal stadium lasts about a week (Subramanyam 1925, Balock and Kozuma 1964, Shukla and Tandon 1985). In our study, pupae were found in four successive collections (Fig. 2). Thus, if the oviposition period occurred within a month, then there must have been much individual variation in larval development rates. If true, then the factors influencing the rate of larval development should be determined, particularly how they affect individual survivorship.

The mango weevil is considered a pest of the mango seed rather than of the flesh. Yet, we found three individuals successfully developing within the pulp. Balock and Kozuma (1964) also reported on a pupating larva that had fed entirely on mango pulp. These observations have serious implications on the control of the mango weevil, particularly on the use of seedless cultivars. If seeds are not required for weevil development, then plant resistance must be based on another mechanism for crop protection.

The fruits, after falling to the ground, were highly susceptible to mammalian attack. Keiser (1959) reported many mango seeds were so damaged by rodents that weevils could not survive. Upon maturation, the adults rapidly moved out of the seeds and sought hiding places. The surface of the Kalapana orchard was gravel and broken lava with many cracks and depressions, thus providing potential overseasoning sites. Van Dine (1906) found many (no numbers given) adult weevils in grooves of wooden fences and crevices in stone walls near mango trees. Typically, the weevils will remain in these sheltered locations until the fruiting season of the following year. The factors which break diapause and motivate the weevils to seek oviposition sites are unknown.

Others (Seo et al. 1974, Shukla and Tandon 1985) reported five instars for the mango weevil, but did not describe how that number was determined. Balock and Kozuma (1964) assumed there were five instars, but commented that their head capsule width data indicated seven instars. The frequencies of our head capsule width data were very similar to those of Balock and Kozuma (1964) (Fig. 3). No discontinuity was evident in the distribution of the smaller measurements which would have been expected if there were only five instars. Also, the range in head capsule width measurements from the known first instar (0.1 mm) to the oldest (1.2 mm) seemed too broad for five instars. However, by taking the measurement of the highest peak (1.3 mm) and progressively dividing the quotient by Dyar's constant of 1.4 (Chapman 1971), one can obtain a close estimate of the head capsule width of the first instar (0.17 mm) after six cycles. As pointed out above, time of individual development may vary greatly and, thus, the number of instars may not be constant. Also, food quality may greatly affect growth and thereby increase the variance around the average head capsule width at each larval instar. Additional work is needed to establish the number of instars in the mango weevil.

The oviposition data suggest that female weevils randomly select the fruit they attack and, hence, do not mark oviposition sites. Also, habitat or tree selection is probably not random considering that even isolated trees were infested. Finally, the mango seed itself must be a nutritious resource considering that five or more individuals can successfully complete development within one seed (Balock and Kozuma 1964).

ACKNOWLEDGMENTS

We thank the following for their contributions to this study: D. Garcia, S. Silva, and T. Menezes for their assistance in the field and laboratory; Warren and Wilbur Yee for allowing us to sample their orchards; Aaron Hagerfeldt and Pacific Paradise Inc. of Kalapana, Hawaii Co., for use of their orchard as a study site; James Tavares in collecting samples on Maui.

LITERATURE CITED

Balock, J. W., and T. T. Kozuma. 1964. Notes on the biology and economic importance of the mango weevil, *Sternochetus mangiferae* (Fabricius), in Hawaii (Coleoptera: Curculionidae). Proc. Hawaii. Entomol. Soc. 18:353-364.

Chapman, R. F. 1971. The insects: structure and function. Amer. Elsevier Publ. Co., Inc., New York. 819 pp.

Jarvis, H. 1946. Pests of mango. Queensland Agric. J. 62:10-14.

Keiser, I. 1959. Observations on mango weevil infestations in 1957. Proc. Hawaii. Entomol. Soc. 17:83-84.

Rutherford, A. 1914. The mango weevil. Trop. Agric. Peradeniya 13:410-411.

Seo, S. T., R. M. Kobayashi, D. L. Chambers, L. F. Steiner, C. Y. L. Lee, and M. Komura. 1974. Mango weevil: cobalt-60 — irradiation of packaged mangoes. J. Econ. Entomol. 67: 504-505.

Shukla, R. P., and P. L. Tandon. 1985. Bio-ecology and management of the mango weevil, *Sternochetus mangiferae* (Fabricius) (Coleoptera: Curculionidae). Int. J. Trop. Agric. 3: 293-303.

Subramanyam, C. K. 1925. A note on the life history of *Cryptorhyncus mangiferae*, Fab. Madras Agric. Dept. Yearbook: 29-36.

Swezey, O. H. 1922. Notes and exhibitions. Proc. Hawaii. Entomol. Soc. 5:13-14.

Swezey, O. H. 1931. Notes and exhibitions. Proc. Hawaii. Entomol. Soc. 7:385.

Swezey, O. H. 1935. Notes and exhibitions. Proc. Hawaii. Entomol. Soc. 9:8.

Swezey, O. H. 1943a. Notes and exhibitions. Proc. Hawaii. Entomol. Soc. 11:270.

Swezey, O. H. 1943b. Notes and exhibitions. Proc. Hawaii. Entomol. Soc. 12:14.

Van Dine, D. L. 1906. The mango weevil. Hawaii. Agric. Exp. Sta. Press Bull. 17:1-11.

Zar, J. H. 1974. Biostatistical analysis. Prentice-Hall, Inc., Englewood Cliffs, New Jersey. 620 pp.