Bio-ecological studies of the mango stone weevil in southern Ghana

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ABSTRACT

Field and laboratory studies were conducted to determine the distribution and biology of the mango stone weevil, *Sternochetus mangiferae*, in southern Ghana. The weevil was found in the coastal savanna and rain forest areas but appeared to be absent from the forest/savanna transition zones. All mango varieties were attacked within the infested zones, with higher rates of infestation in the more humid areas. Elsewhere, the weevil is reported to contribute substantially to premature fruit drop and causes reduction in yield. The eggs appear to be laid in young fruits over a period of time as some fruits recorded multiple infestations with all stages of development observable in a single fruit. In the laboratory both larvae and adults were reared on excised mango cotyledons, but it is doubtful that adults survive on cotyledons in the field. Larvae pupated for 6-7 days with a pre-pupal stage of 1-2 days. Adults are long lived and have been cultured in the laboratory for up to 6 months. Adults were found hibernating in cracks and crevices on trunks of old mango trees (> 20 years after planting). Similar hiding places could not be found on young trees (≥ 10 years after planting). It is, thus, possible that trees other than mangoes provide hibernation sites for the weevil between fruiting seasons. Adult weevils readily accepted and climbed onto flowers but did not show any preference for bark, twigs, leaves or soil. The acceptance of the flowers by the adults seems to suggest that flowers may provide food and breeding sites. Infestation by the weevil did not affect fruit quality despite the high potential to disrupt the export trade in mangoes. The low quarantine rejection threshold of one fruit in 40 set in the export market suggests that solution to the problem posed by the weevil requires socio-economic, political and scientific initiatives.

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Introduction

The mango stone weevil, *Sternochetus mangiferae* (F), is a major quarantine pest of mangoes in producing areas of the world (CAB & EPPO, 1997). The weevil causes premature drop of young fruits (Shukla & Tandon, 1985; Pena, Mohyuddin & Wysoky, 1998; Follett, 2002). It destroys the mango cotyledons and embryos, and was reported to cause reduction in seed viability and germination (Peñe *et al*., 1998). This could reduce the availability of planting materials for propagating of mangoes. However, recent studies conducted by Follett & Gabbard (2000) show that feeding by the weevil did not reduce germination rates significantly in poly-embryonic mango varieties. The weevil is yet to be proven to affect the quality of the fruit as pulp feeding is rare, occurring in some 0.3 per cent mangoes (Hansen, Amstrong & Brown, 1989; Hansen & Armstrong, 1990).

S. mangiferae is considered a serious pest in Ghana because of the developing export trade in mangoes. The international quarantine infestation threshold of the mango weevil is 2.5 per cent (i. e. one out of 40 fruits) (Soe *et al.*, 1974; Bagshaw *et al.*, 1989). This rather low threshold requires that serious attention is paid to the problem posed by the weevil. The paper reports on preliminary work conducted at the Crop Research Institute, in an effort to understand the bio-ecology of the weevil and determine the relationships between it and the mango plant. The results could provide the framework for the development of sustainable pest management strategies to control the weevil.

Materials and methods

Regular sampling

Mango fruits were collected from a mango orchard at the Kwadaso Station of the Crops Research Institute, Kumasi, on a weekly basis during the major mango fruiting season (April-June 1997), and dissected to determine their infestation by *S. mangiferae*. Samples were taken from three exotic or improved varieties (Sunset, Keitt and Jaffna) and a local check. Measurements were taken of fruit size, mesocarp thickness, seed size and seed coat thickness, using a 0-150 mm dial callipers. The number and stage of development of weevils found was recorded. Adult weevils that were found were reared in Kilner jars and fed with dilute honey solution on cotton swabs and excised mango cotyedons. Larvae and pupae were reared in Petri dishes and Kilner jars until adulthood. The larvae were fed on excised mango cotyledons.

Survey

Further to the regular sampling of mangoes, a survey was conducted in Southern Ghana between April and June 1998 to establish the distribution of the weevil, ascertain any alternative host plants, and discern any relationship between ecological factors and the distribution of the weevil. The survey covered most of southern Ghana, Kintampo and Wenchi to the west, and Hohoe to the east, being the northern most limits. The route was pre-determined to follow the major roads. Stops were made in towns or villages at between 10- and 25-km intervals. Twenty fruits were harvested from either single tress or groups of trees. Fruits harvested during the survey were mostly mature. The fruits were picked from the canopy at about 2 m from the ground, or, where necessary, with the assistance of a stick or other device for plucking fruits. Where several varieties could be found, fruits were picked from all varieties. The survey of south-western Ghana was carried out in August 1998, when the mango season was almost over, hence, only few fresh fruits could be obtained. Nevertheless, mango seeds were collected from under the tress and assessed for weevil damage and exit holes. In cases where the seeds were not dried up, larvae, pupae and adults could be found.

Laboratory studies

Hibernating place. A laboratory experiment was conducted to find out the places where the weevils hibernate after emergence from the mango seed. Three soil types comprising washed river sand, sandy loam from under a grass fallow and loam from under a mango tree were used as test soil material. Kilner jars were filled with the soil to within 2.5 cm of the top. Ten adult weevils were placed in each jar and allowed a period of 2 weeks to bore into the soil. The experiment was replicated three times.

Preference for host plant parts

A test of the weevil's preference for parts of the mango plant was performed by exposing 10 adult weevils at a time to pieces of bark, twigs and leaves in a two chamber olfactometer. Each test material was tested against an empty chamber. Each of the tests was repeated six times.

Results and discussion

Regular sampling

The data from the measurements of fruit characteristics were analysed by ANOVA using MSTAT C and are presented in Table 1. The mango varieties differed significantly ($P < 0.05$) in fruit and seed size but not in mesocarp, seed coat thickness and number of weevils (Table 1). It, however, appeared that Keitt was more vulnerable to weevil attack due to factors that were not determined in this study. Seed coat hardness was not measured and no relationship between seed coat thickness and hardness was established. Also, observations of thicker seed coats for the local variety did not translate into sigificantly less infestation (Table 1). It is probable that the size of the fruit and seed are more important in determining the number of weevils it can support but are not as important to the weevil's survival as the ease with which early larvae bore into the seed to feed on the cotyledons.

Incidence and distribution of the weevil

A total of 2269 fruits were dissected from 108 locations during the survey. Six hundred and seventy six weevils were found in 603 infested fruits mainly because of multiple infestations in some fruits. In one case, as many as six weevils were found in the fruit. There were also instances where only signs of fruit infestation could be found but no weevils were observable. This represented an overall infestation rate of about 28 per cent. Observations indicated that the forest transition areas were relatively free of the weevil. Thus, mangoes collected from Kpando, Hohoe, Leklebi, Wenchi, Techiman and Nkoranza were all noted to be free of the weevil. Mangoes from Ejura showed low infestation levels. Out of 100 fruits of Keitt, Jaffna, Palma, Haden and the local variety, only one fruit of Keitt was infested. This represented some 1 per cent infestation. However, some areas within the forest regions, such as Koforidua and Bunso, in the Eastern Region, were also found to be free of the weevil (Fig. 1). As these towns are in the forest region, the absence of the weevil was an unexpected result. Similarly, some areas in the coastal parts of the Central Region were apparently free of the weevil. This could be attributed to the fact that mangoes were

TABLE 1

Fruit Characteristics of Four Mango Varieties at Kwadaso between April and June 1998

Variety	*Fruit size (cm^3)*	*Mesocarp thickness (mm)*	*Seed size (cm^3)*	*Seed coat thickness (mm)*	*Mean weevil count*
Sunset	255.87d	17.32	20.25c	0.87	3.6
Keitt	206.56c	13.74	8.54a	0.64	4.2
Jaffna	143.33b	13.91	13.14b	0.62	1.7
Local	98.88a	13.47	10.21b	0.86	0.8
LSD (5%)	43.36	N.S.	2.96	N.S.	N.S.

Numbers followed by the same letter in a column are not significantly different ($P < 0.05$).

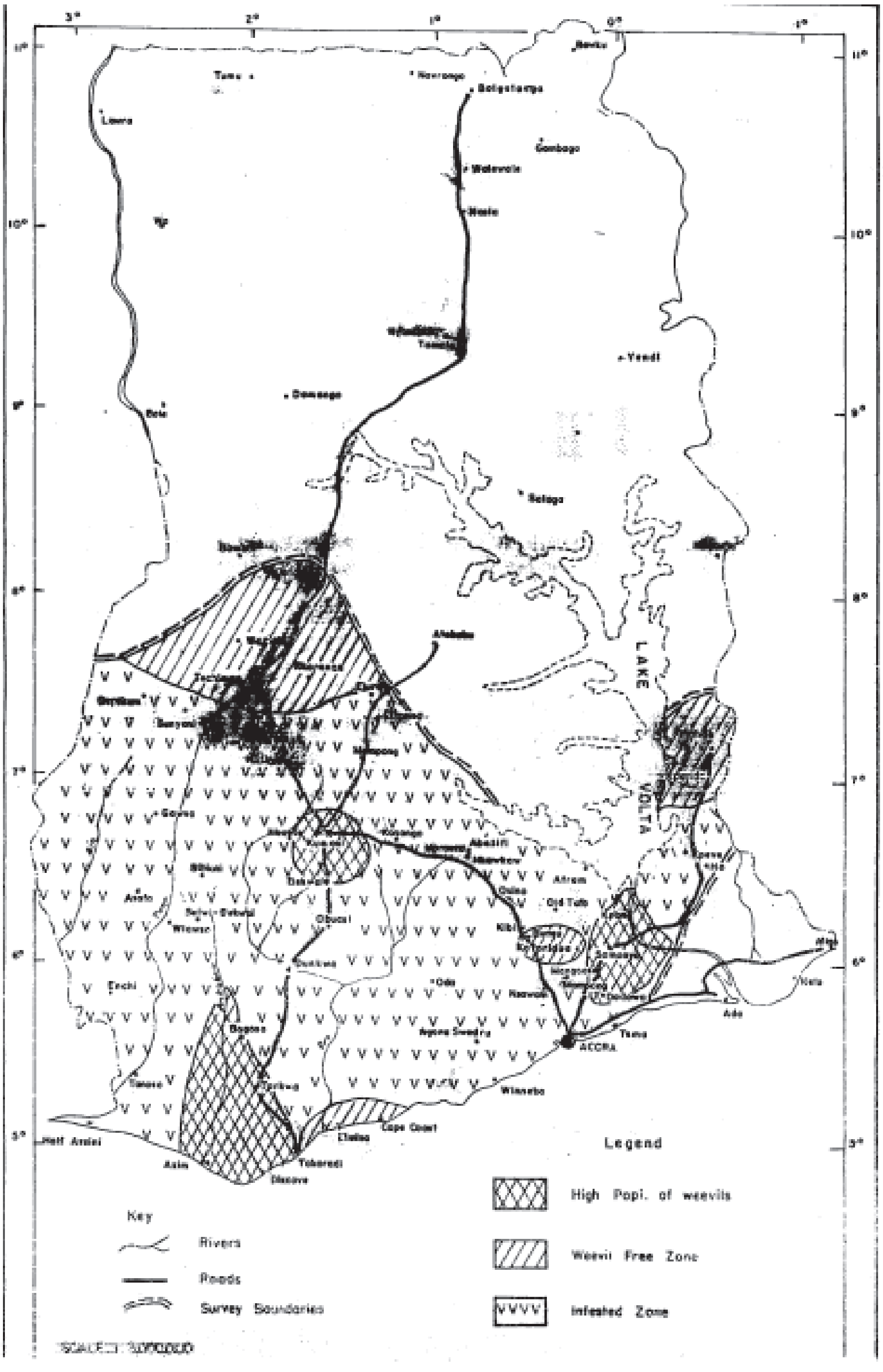

Fig. 1. Map showing the survey area and distribution of *S. mangiferae* in southern Ghana.

virtually out of season (June 1998) and only few late fruits could be obtained.

Weevil populations were highest around the Volta basin, the Accra plains and in the other parts of the forest region. In the forest, higher weevil populations were found on mongoes growing in cocoa or palm plantations. For example, out of 55 fruits collected from a single mango tree in a cocoa plantation at Gyaaman in the nothern end of Central Region, as many as 47 (85%) were infested by the weevil. Many of these fruits also showed multiple infestations. In Somanya, where the largest number of varieties (Julie, Keitt, Haden, Local Jacquilene and Urwin) was collected, the average infestation was 49.33 per cent. Atimpoku recorded a mean fruit infestation by weevils of 62.5 per cent while for Palma, collected in Dodowa, 100 per cent infestation was recorded.

Varietal preferences. The estimated mean percentage fruit infestation was calculated as a cumulative mean for the means of infestation of the fruits for each variety for the number of locations at which it was found (Table 2). The precentage fruit infestation (Table 3) was estimated by dividing the number of infested fruits in a variety by the total number of fruits collected for the variety. The probability that a fruit of a variety was infested (Table 3) was calculated by dividing the total number of weevils from fruits of the variety from all locations by the number of fruits collected for the variety. The probability of infestation reduced as the number of fruits increased and differed from the percent fruit infestation because ssome fruits had more than one weevil.

S. mangiferae was found in all mango varieties sampled during the survey except for Spingfield and Abidjan (Table 3). The largest number of fruits was collected from the local mango cultivars, which appeared to suffer similar infestation levels as the exotic or improved varieties. Keitt was both the most widely cultivated exportable exotic variety and the one most infested by the weevi (Tables 2 and 3). It is possible that this is a result of its relatively lighter seed coat thickness (Table 1) and the larger fruit and seed size. Jaffna was also widely cultivated but showed one of the least infestations (Table 3). It was difficult to compare the varieties because of the disparities in the numbers of fruits collected (Table 3). However, wherever the mangoes were infested all the varieties suffered higher levels of attack than the 2.5 per cent international quarantine threshold (Tables 2 and 3).

TABLE 2

Trend of Infestation of Mango Varieties Collected in Southern Ghana by the Mango Stone Weevil, Sternochelus mangiferae

Variety	*Number of locations*		*Percent mean estimated fruit infestation*
	Surveyed	*Infested*	
Local	59	39	27
Jaffna	14	7	16
Keitt	8	7	39
Kent	3	3	34
Haden	6	4	22
Sunset	2	1	29
Palma	2	1	50
Springfield	1	0	-
Jacqueline	3	1	33
Julie	1	1	70
Urwin	1	1	3

Ecology and biology. Even though no conscious attempt was made to gather data on the relative humidity levels of the sampling sites, there appeared to be some releationship between the relative humidity within any environment and the levels of infestation of the fruits. This might explain the prevalence of the weevil in the forest areas, especially around established cocoa farms where humidity is usually relatively high throughout the year. This apparent relationship between relative humidity and the infestation

TABLE 3

Distribution and Probability of Infestation of Varieties of Mangoes by the Mango Stone Weevil, Sternochetus mangiferae *in Southern Ghana*

Variety	*Number of fruits collected*	*Percent of fruits infested*	*Probability that a fruit is infested*	*Percent multiple infestation of fruits*
Kent	55	38	0.89	0
Keitt	133	35	0.49	13
Jaffna	279	17	0.31	4
Sunset	43	25	0.72	28
Local	1486	28	0.25	7
Haden	95	17	0.22	4
Exotic	51	14	0.22	6
Palma	30	33	0.75	27
Julie	10	30	0.60	10
Urwin	10	70	0.30	0
Jacqueline	40	40	0.70	23
‡Springfield	10	20	0	0
‡Abidjan	10	0	0	0

‡ = Samples were picked from only one location.

of mangoes by *S. mangiferae* could also explain the high populations of the weevil in the Volta Lake basin (Somanya, Dodowa and Atimpoku) (Fig. 1) and the coastal areas around Discove.

It was observed in several locations that several weevils at different stages of development could be found in a single fruit. This situation was observed in several locations. Multiple infestations were seen as indications that several eggs were laid into a single fruit. This is probably an indication that ovipositing weevils do not mark their host. It may also indicate that where there is enough food, the larval weevils are not canibalistic. There was no instance where more than one exit hole was found on a fruit or seed. This was seen as an indication that even when the seed contained several weevils only one exit hole was necessary for the escape of all adult weevils.

The duration of the pupal stage was 6-7 days, with a pre-pupation period of 1 to 2 days. The adults were generally long lived and could survive under laboratory conditions for more than 6 months. The adult weevil is reported to live up to about 300 days (Shukla & Tandon, 1985). Adults fed on both honey and cotyledons of the mango seed in the laboratory. However, it is not likely that they survive on cotyledons after emerging from the mango seed since the material is not readily available. Adult weevils were attracted to mango flowers and appeared to feed on nectar and pollen. Attraction to plant parts has been reported in other weevils (Bartlet *et al.*, 1993; Braimah, 1997). The attraction of *S. mangiferae* to flowers probably explains how it moves out of its hideouts into flowering and fruiting mango trees. It is possible that the odours of the flowers provide the cues that direct the weevils to the host plant after hibernation and that while feeding they also mate and deposit eggs in developing fruits.

In the study to find out the weevil's place of hibernation after emergence from the mango tree, observations indicated that the weevils did not hibernate in sand, sandy loam from under a bush fallow or loamy soil from under a mango tree under laboratory conditions. There is also no indication in the literature that the weevil lives in the soil after emergence. Weevils were found in crevices and cracks on the barks of old trees even though none showed preference for pieces of bark when they were allowed to choose between bark and air. Shukla & Tandon (1985) also reported that the weevils diapause in crevices on the bark of the tree after emergence from the stones (seeds). It, however, appears that the mango bark may not be the only hibernation site for the weevil. Younger mango trees have rather smooth barks that can not shield the weevils from the environment and natural enemies between fruiting seasons. Nonetheless, during the survey weevils were found from plantations that are less than 10 years old with relatively smooth barks. This suggests that the weevil may hibernate in areas other than mango bark, especially in crevices and cracks on other tree barks.

The exotic varieties tended to have a higher proportion of fruits suffering multiple infestations (Table 1). The number of weevils found in a fruit probably depends on the number of eggs deposited in it and the availability of food material to support the developing larvae. It was not conclusive whether all the weevils in a fruit were offspring of one female. However, the fact that larvae, pupae, and adults could all be found in one fruit suggests that the eggs were laid over a period of time, probably by different weevils. It is likely that eggs are deposited on fruits at an early stage of fruit development, hatch and the larvae enter the fruit while the seed coat is soft and the cotyledons are just developing. The fruit then recovers from any injury caused by the penetrating larvae. Eggs and early larval stages were difficult to find in the fruit. This explains why fruits that were dissected at the golf ball stage appeared to be free of the weevil. This notwithstanding, fruits that were caged at the golf stage were later found to be infested when they were dissected at maturity. Cunningham (1984) reported that egg deposition started when fruits were 30 mm long and continued until a month before maturity. At Kwadaso, it was observed that most fruits that dropped prematurely from the cultivars Sunset and Keitt were infested with the weevil. Bagle & Prasad (1985) recorded similar results when they studied the responses of several mango varieties to infestation by the weevil in India.

The results of the study suggest that the infestation levels of mangoes by the weevil on all mango varieties in areas of southern Ghana where the weevil is established are higher than the international quarantine threshold of 2.5 per cent. The forest/savanna transition zone appears to be the best area for the production of mangoes for export if the quarantine problems associated with *S. mangiferae* are to be avoided. It may be necessary to institute legislative controls to prevent the introduction of the weevils into these areas through the movement of fruits across boundaries as a contribution to the integrated management of the weevil. The weevils hibernate in cracks and crevices on the bark of older host trees between mango fruiting seasons. The distruction of old local mango trees around orchards of exortic varieties could reduce hibernation sites and, thus, populations of diapausing weevils. Through the combination of judicious band application of contact acting persistent insecticides on tree trucks, trapping of weevils with sticky traps, application of non-persistent insecticides with quick knock down effect on weevils at flowering, and the destruction of dropped and discarded fruits, the population of the weeebvils could be reduced significantly.

On the contrary, the use of flowering to break the alternate bearing habits of the mango tree and provide fruits throughout the year may enhance the build up of weevil populations. These notwithstanding, the probability that these suggested control measures can reduce infestation rates to levels below the 2.5 per cent international quarantine threshold is very low. Elsewhere, combination of similar treatments only reduced infestation levels from 87 to 24 per cent (Dey & Pande, 1987). There is, therefore, a need to initiate economic and political negotiations between the exporter and the consumer countries to establish an achievable *S. mangiferae* threshold to save the growing Ghanain export trade in fresh mangoes. Failure to obtain such agreement may require the conversion of mangoes into other finished industrial products such as jams before their export.

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