

EVALUATION OF TRAPS AND ATTRACTANTS FOR MONITORING THE MANGO STONE WEEVIL *STERNOCHETUS MANGIFERAE* (COLEOPTERA: CURCULIONIDAE) IN MANAGED ORCHARDS IN SOUTHERN GHANA

Anderson R.S.¹, Tantoh D.M.¹, Akotsen-Mensah C.^{2*}, Osei-Safo D.³ and Afreh-Nuamah K.^{1,2}

¹African Regional Postgraduate Programme in Insect Science, P.M.B L59, University of Ghana, Legon, Ghana.

²Forest and Horticultural Crops Research Centre, School of Agriculture, College of Basic and Applied Sciences, University of Ghana, Kade, Ghana.

³Department of Chemistry, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana.

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Field studies were conducted to identify the most effective traps and lures in attracting the mango stone weevil in managed mango orchards in southern Ghana. Two field experiments were conducted during two mango seasons of 2013/2014 and 2014/2015 respectively. In 2013-2014 season, four traps types namely black pyramid, yellow pyramid, Circle, and cone emergence traps were evaluated to determine the most effective trap for capturing mango stone weevil in a managed orchard in southern Ghana: The number of mango weevils captured during each sampling period was used as a measure of trap effectiveness. Among the four traps evaluated, the black pyramid and Circle traps performed significantly better compared with the cone and yellow pyramid traps. The highest number of mango stone weevils captured coincided with the period of mango plant bloom. In 2014-2015 cropping season, the black pyramid and Circle traps were selected for further evaluation in association with single and double combinations of benzaldehyde (BZ) and essential oil (EO) obtained from the mango blossom. The addition of the attractants did not significantly improve trap captured even though the black pyramid trap captured about 6-fold compared to the Circle trap. The release rate (2.55mg/hour and 1.80mg/hour) of the BZ was significantly higher than the essential oils (2.18mg/hour and 1.48mg/hour) in both the laboratory and mango orchard.

Key words: *Sternochetus mangiferae*, Mango Stone weevil, Benzaldehyde, Essential oils.

INTRODUCTION

The Mango stone weevil *Sternochetus mangiferae* Fab (Coleoptera: Curculionidae) is a key pest of

mango *Mangifera indica* L. in most mango producing countries including Ghana (Braithwaite and Van Emden, 2010). The insect is important in mango production because mango is the only known host plant (Braithwaite and Van Emden, 2010). The stone weevil is recognized as one of the key international quarantine pest of importance and its presence in the production system poses sufficient

 *Corresponding Author Email: cakotsen-mensah@ug.edu.gh and nimako60@gmail.com.

reasons for rejection of fruits on the export market (Braumah and Van Emden, 2010; Arthur et al., 2009). Their presence in mango fruit also requires that stringent management practices are applied and this increases cost of production. The persistence of mango stone weevil as a pest of mango has been attributed to the fact that although it has natural enemies, the natural enemies are not capable of providing sufficient controls in both treated and untreated orchard due to the cryptic behaviour of the stone weevil; and no effective natural enemy specific to the weevil has been recorded (Pena et. al., 1998; Peng and Christian, 2007). Furthermore, as a direct pest which spends its egg, larval and pupal stages entirely inside the fruit, controlling them is a major challenge with the adult stage as the most convenient target for control if insecticides must be used.

Limited literatures on the biology and behavior of mango stone weevil are only available thereby leaving several questions unanswered concerning its ecology and management. For instance, the factors mediating movement of mango stone weevil from aestivating sites to trees are very scanty, however, lack of accurate and convenient methods for estimating mango stone weevil population density, particularly, in the early cropping season, and the associated lack of information on mango stone weevil migration behavior have prevented the development of comprehensive integrated pest management programmes for mango in Ghana. An important initial step to the development of integrated pest management is pest monitoring. This is essential for providing an effective control measure, particularly, when insecticides form the major part of the control programme. Pest management decisions are often made based on the results of sampling methods using traps and lures indicators. An important criterion for any trap monitoring programme used for short-term pest forecasting is the consistency of relationship between trap captures and corresponding field infestation. Therefore, monitoring programmes developed for many insect pests have not achieved this important criterion in that pest infestations have usually proceeded before trap detection (Prokopy et al., 2000; Leskey and Wright, 2004a).

In pest management, trap and lure types have been examined for monitoring purposes in many cropping systems. However, the efficacies of the lures deployed in traps have shown good potential

in some studies with corresponding poor results in other studies. In spite of some successes recorded in the use of baited traps in monitoring programmes in many fruit growing regions, a number of factors in the field had been reported to greatly influence the performance of baited traps. Some of the specific problems that were identified for the ineffectiveness of the traps and lures used in monitoring include competition of natural odors from host plants and prevailing environmental conditions in the field. For example, Leskey and Zhang (2007) reported that the performance of baited traps for monitoring adult plum curculio in apple orchards in West Virginia was greatly influenced by low spring temperatures in the field studies. The effect of temperature was seen, for example, in the rapid degradation of the volatile lure constituents resulting in reduced effectiveness as disproportionate loss of a single lure component can render these compounds behaviorally undetectable (Bartelt, 1999).

The potentials for use of host odour baits combined with pheromones have also been reported in several genera of the subfamily Curculioninae (Bartelt, 1999), to which mango stone weevil belongs, and investigations have documented the synergy of host plant materials and pheromone combinations in enhancing trap captures (Landolt and Phillips, 1997). Semiochemicals have currently been used as a successful tool in pest management of weevils in annual and perennial crops like peach, apples, cotton, coconut, and sweet potatoes (Leskey and Wright, 2004b; Akotsen-Mensah et al., 2010).

The considerable differences in conditions across locations coupled with the dependence of most lures on temperature-driven mechanisms of release of olfactory stimuli (Leskey and Zhang, 2007), suggest that lures must be evaluated on a regional and local basis before recommendation for grower use. The objective of this study was to evaluate the effectiveness of two widely used trap types using two host based fruit volatiles for monitoring populations of mango stone weevils in mango orchards in Ghana.

Data from this study, in addition to a degree day model being developed, will provide aid in the development of monitoring techniques and sampling guidelines for mango stone weevil in mango orchards in Ghana. Tools for pest monitoring and evaluation such as trapping and lures were therefore tested for their effectiveness in three

mango orchards in Southern Ghana.

MATERIALS AND METHODS

Trapping experiments in 2013-2014

This work was conducted at Somanya (Latitude 6°00' and 0°30' N and Longitude 0°30' E and 1°00' W) in the Yilo-Krobo District of the Eastern region of Ghana with an altitude of 457.5m above sea level. Somanya is one of the major mango producing areas in Southern Ghana. It is among those areas reported to be endemic to stone weevil (Braumah and van Emden, 2010). It is located in the coastal savannah ecological zone. It experiences a bi-modal rainy season which runs from March to July (major season) with a short break in August and September to November (minor season) and rainfall reaches its peak from May–June. The dry season runs from December to February. The average annual rainfall is between 750 mm in the Lower Yilo-Krobo and 1600 mm on the slopes of the ranges in the Upper Yilo-Krobo. Average temperature ranges from 24.9°C to 29.9°C. Furthermore, there is a characteristic average relative humidity ranging from 60-93 %. Harvesting is from mid-May to July for the major season and December to February for the minor season.

The management practices in the orchard

The 8.8-hectare orchard (Sabano Farms) used for the study belonged to a farmer. The common varieties cultivated in the orchard included Keit (80%), and the rest Kent, Palmer, Haden and Irwin constituted 20% of the trees.

Pest management practices common to the farm are the use of synthetic pesticides such as deltamethrin, acephate and carbaryl and cultural practices such as picking and destruction of dropped fruits. A total of 3-6 insecticide applications were made within the season. Insecticide application stopped two weeks before harvesting. The common weed control was the use of herbicides and about 2-4 applications were done during each fruiting season.

Trap placement

The traps evaluated were Circle, black pyramid,

yellow pyramid and cone emergence traps (Figure1). The circle and black pyramid traps were purchased from Great Lakes IPM Inc. (Vestaburg, MI) while the yellow pyramid and cone traps were locally constructed. The yellow pyramid traps were constructed using plywood painted with yellow paint while the cone emergence were constructed using fine mesh aluminum and attached to wood planks (Figure 1).

The placement of the traps was done following the procedures used by Prokopy et al. (1999) and later adopted by Akotsen-Mensah et al., (2010). Briefly, the traps were located between two trees of 30m distance apart. The Circle traps were wrapped around the tree trunk of ~50 cm from the ground with the help of cotton wool strings. To ensure a firm attachment of the traps to the trunk, thumb tags were used to pin the traps to the trunk. The black and yellow pyramid traps were placed 60 cm away from mango trunk and were fastened to the ground with the help of plastic rods to ensure firmness. The cone emergence was made with a fine mesh aluminum net attached to a three wooden stand made in the shape of a cone. The trap was capable of housing over 10 fruits (both freshly plugged and “dropped/decaying” fruits). The weevils that emerged from the fruits under the cone emergence trap migrated to the top of the boll through a hole inside the trap and remained there until collections were made.

All the traps were re-randomized every two weeks to exclude or minimize any effect that may be attributed to location. The traps were deployed in the mango orchard for a period of 40 weeks from 26 June, 2013 to 26 March, 2014. During each week, the number of stone weevils collected, were counted and recorded. Pyramid traps were placed closer about 0.6m to a mango tree trunk and incisions were nailed to the ground with plastic pegs for firmness.

Circle traps were wrapped with masking tapes at random around the main trunk of the trees selected for trap placement. The traps were separated by three trees, making a total distance of 30 m between each trap.

Traps were deployed in the orchard as soon as the seasons began. Traps were inspected twice in a month for mango stone weevil. Counting and recording of the number of weevils captured per trap was done and continued throughout the fruiting season.



Black pyramid trap



Circle trap



Cone emergence trap



Yellow pyramid trap

Figure 1. Pictures of traps used for the field study. Upper left (Black pyramid trap), upper right (Circle trap), bottom left (Cone emergence trap) and bottom right (Yellow pyramid trap).

Trapping experiment 2014-2015

In this study, black pyramid and circle traps were selected as the most promising among the four traps for further evaluation in two districts: Eastern region (Yilo and Manya Krobo) and one district in Greater Accra Region (Shai Osudoku). In each district, one mango orchard was selected for the evaluation of the trapping and monitoring activities. Farm sizes of 20.8-ha, 8.8-ha and 8.0-ha located at Kpong (Manya Krobo), Somanya (Yilo Krobo) and Ayikuma (Shai Osudoku) respectively, were used. In each of the traps, two attractants namely

benzaldehyde (BZ), and essential oil (EO) (extracted from mango flowers by cold percolation using ethyl acetate) were evaluated for their effectiveness in attracting the mango stone weevil. Similar procedures in 2013 were used to install the traps. The traps were set up in a randomized complete block design (RCBD). Each orchard was divided into four blocks and the following eight treatments; Pyramid trap only, Pyramid trap + BZ, Pyramid trap + EO, Pyramid trap + BZ + EO, Circle trap only, Circle trap + BZ, Circle trap + EO, and Circle trap + BZ + EO, were randomized per block in each orchard. For each of the baited traps, a single

dispenser containing ~5 mL of benzaldehyde and/or essential oil was deployed in small polyethylene vials and placed inside the plastic, funnel shaped top attached to the tip of each trap.

The release rate of attractants

The release rates of the two attractants were determined gravimetrically in the orchards. This was done by determining the differences in the initial weights and subsequent daily weights; this was used to determine the release rate per day. The release rate per day was further divided by 24 to determine the release rate per hour. This was repeated in the laboratory to compare the release rates at constant temperatures. The essence of this was to determine the amount of attractant released per given weather conditions which could be used to explain trap captures. Whereas some insects may respond to high doses of attractants others may require low doses. This experiment was conducted between 5th February to 12th May, 2015 in a research farm planted to mangoes at FOHCREC, Kade. The vials were obtained from VWR Scientific Products; Boston, MA. All vials containing BZ and EO were replaced on 15th February 2015 and experiment was repeated.

Statistical Analyses

Mango stone weevils captured in the traps (2013-2014) and the traps and lures combinations (2014-2015) during each sampling day were recorded and used for all analyses. Thus, the data units for the field experiments were number of mango stone weevils captured/trap/sampling date for both the major and minor mango seasons. The trap captures were transformed where necessary by using $(x + 0.5)^{1/2}$ (Ahrens et al., 1990), when the assumptions of ANOVA were seen to have been violated. Data were first analyzed using standard least square analyses of variance to determine the effects of sampling date and trap type for the 2013-2014 data and sampling date, trap type, lure type, and location. Trap type and their interactions were also determined during the 2014-2015 study. Treatments which showed significant effects and their interactions were further analyzed either by a Student's t-test (two treatments only) or analysis of variance ([ANOVA]; more than two treatments) for each orchard for both seasons. Means were

separated using Tukey-Kramer Honesty Significant Difference at $P = 0.05$.

RESULTS

Trapping experiments in 2013-2014

The peak trap captures in 2013-2014 occurred during fruit development stage from early to late October when fruits were at marble size (Figure 2A). The highest trap captures were recorded during bloom in mid-August and early September. A total of 102 adult stone weevils were captured by all the trap types during the 40 weeks of sampling. During the major rainy season, a total of 23 adults were captured. The standard least square ANOVA showed no significant difference in the trap type ($F = 1.63$; d.f = 3; $P = 0.1817$) and trap type sampling date interaction ($F = 0.87$; d.f = 117; $P = 0.8701$). However, there was significance difference in the sampling date ($F = 3.29$; d.f = 39; $P < 0.0001$). Because there was no significance difference among the treatment, a one-way ANOVA was performed on the pooled data. The results of the one-way ANOVA of pooled data showed significant difference among trap types per sampling week ($F = 5.11$; d.f = 3; $P < 0.0020$). The black pyramid trap captured more weevils (mean: 0.288 ± 0.094) compared to the Circle (mean: 0.042 ± 0.042), the cone emergence trap (mean: 0.037 ± 0.026) and the yellow pyramid trap (mean: 0.015 ± 0.015) during the major rainy season. Comparatively, the black pyramid trap significantly captured more weevils than the cone emergence and the yellow pyramid, but not the Circle trap (Figure 3).

During the August break (a short transitional period between the major and minor rainy seasons), a total of 19 mango stone weevils were captured. One-way ANOVA of pooled data showed no significant difference among trap types ($F = 0.55$; d.f = 3; $P = 0.6511$) for the weekly captures. The Circle trap captured more weevils (mean: 0.250 ± 0.144) compared to the yellow pyramid (mean: 0.159 ± 0.080), the cone emergence trap (mean: 0.139 ± 0.114) and the black pyramid trap (mean: 0.068 ± 0.038), though the differences were not significant (Figure 3). In the minor rainy season, 31 adult mango stone weevils were captured. Results of one way ANOVA showed no significant difference among the trap types. The Circle trap captured more

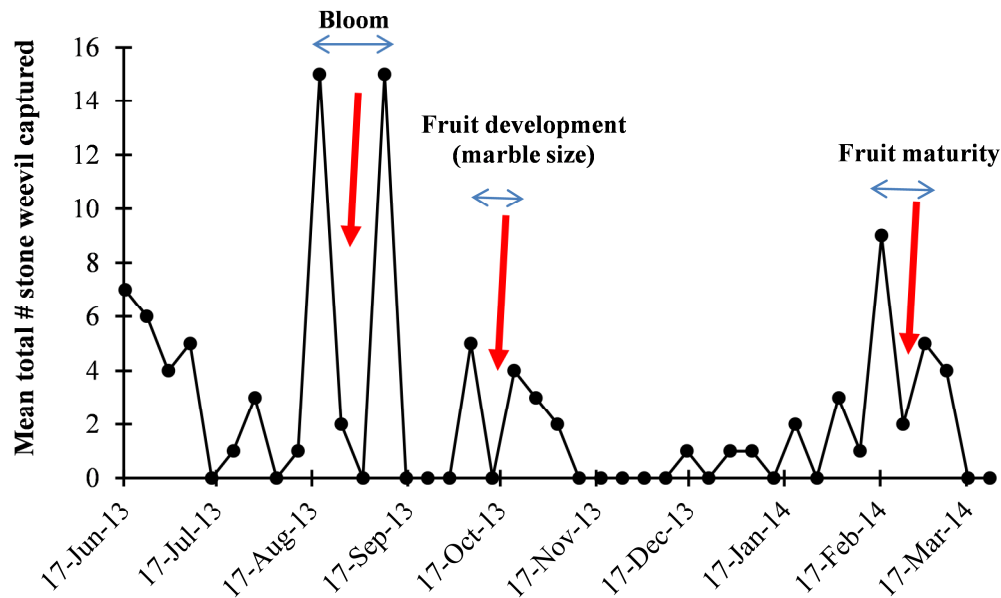


Figure 2A. Mean total weekly trap captures of mango stone weevils in A: 2013-2014 mango seasons.

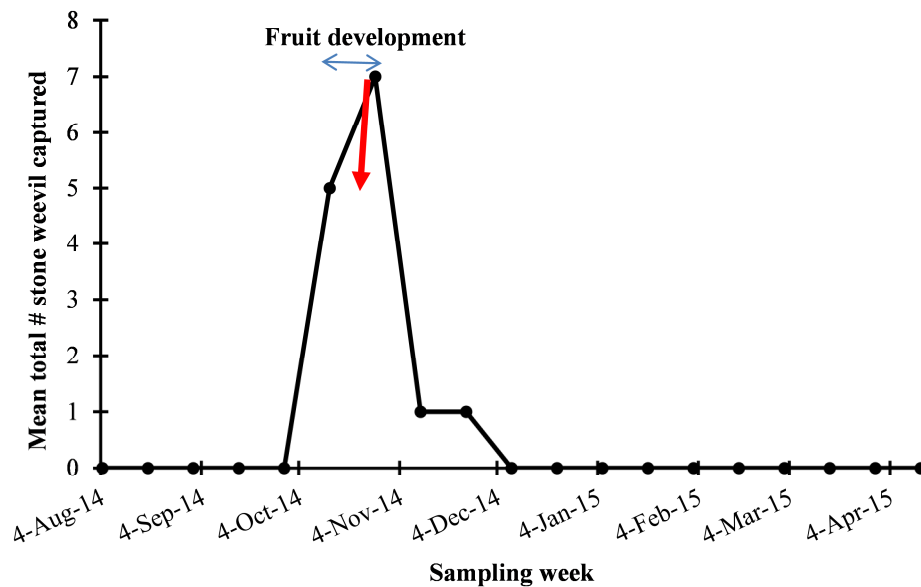


Figure 2B. Mean total weekly trap captures of mango stone weevils in B: 2014-2015 mango seasons.

weevils (mean: 0.13 ± 0.05) compared with the black pyramid (mean: 0.08 ± 0.03), the yellow pyramid trap (mean: 0.06 ± 0.02) and the cone emergence trap (mean: 0.03 ± 0.02), even though the differences were not significant (Figure 3). In the

dry season, 29 adult mango stone weevils were captured. Results of one way ANOVA of the pooled data showed no significant difference among trap types. The Circle trap captured more weevils (mean: 0.06 ± 0.04) compared with the cone emergence

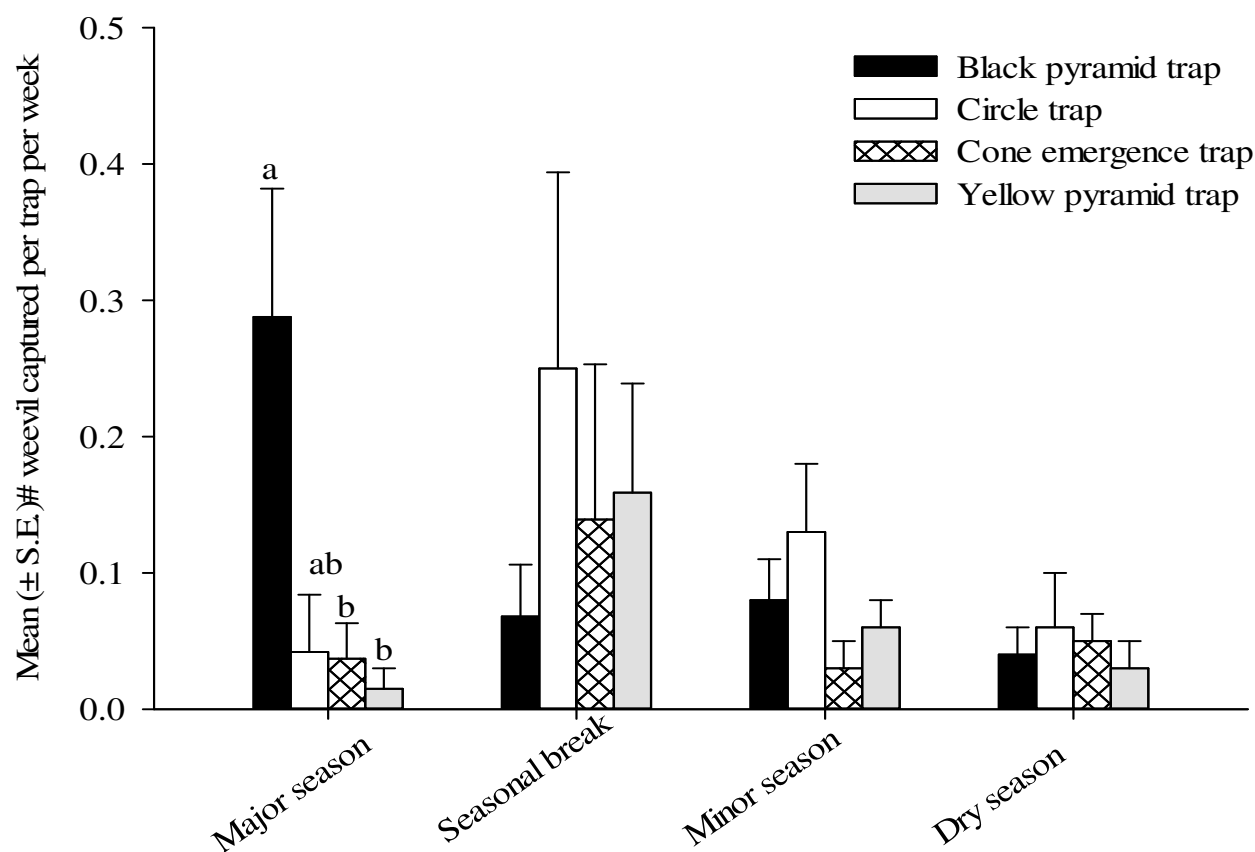


Figure 3. Mean ($\pm$ S.E.) of the weekly trap captures of mango weevils during different seasons in 2013. Levels connected by the same letter are not significantly different at $P = 0.05$.

(mean: 0.05 ± 0.02), the black pyramid (mean: 0.04 ± 0.02) and the yellow pyramid trap (mean: 0.03 ± 0.02) (Figure 3).

The traps captured adult mango stone weevils in all the phenological stages of the mango crop listed below except during fruit set (Table 1). Most of the insects were captured during the blooming period and the circle trap recorded peak capture during this period.

Trapping experiments in 2014-2015

The peak trap capture during the 2014-2015 also occurred during fruit development from early to late October when fruits were about a marble size (Figure 2B). The standard least square ANOVA of the data showed significant differences among the locations ($F = 3.89$, d.f. = 2; $P = 0.0248$), trap type ($F = 5.55$, d.f. = 1; $P = 0.0212$), lure type ($F = 3.21$, d.f. = 3; $P = 0.0281$) and the interaction between

trap type and lure type ($F = 3.6$, d.f. = 3; $P = 0.0174$). However, the interaction between location*trap type ($F = 1.49$, d.f. = 2; $P = 0.2326$), location*lure type ($F = 0.98$, d.f. = 6; $P = 0.4463$) and location*trap type*lure type ($F = 1.45$, d.f. = 6; $P = 0.2072$) were not significant. Because the interaction of location*trap type and location*trap type*lure type were significant, a one way ANOVA was performed on the lure and trap type without recourse to location since both location and trap type, and location and lure type were not significant. The results showed that there was no significant difference among the lure type for the two traps (Figure 4).

Although no significant differences were observed among the two traps, the pyramid trap captured numerically more adults than the Circle trap. The pyramid trap (control) recorded numerically more stone weevils compared with the other treatments (Figure 4).

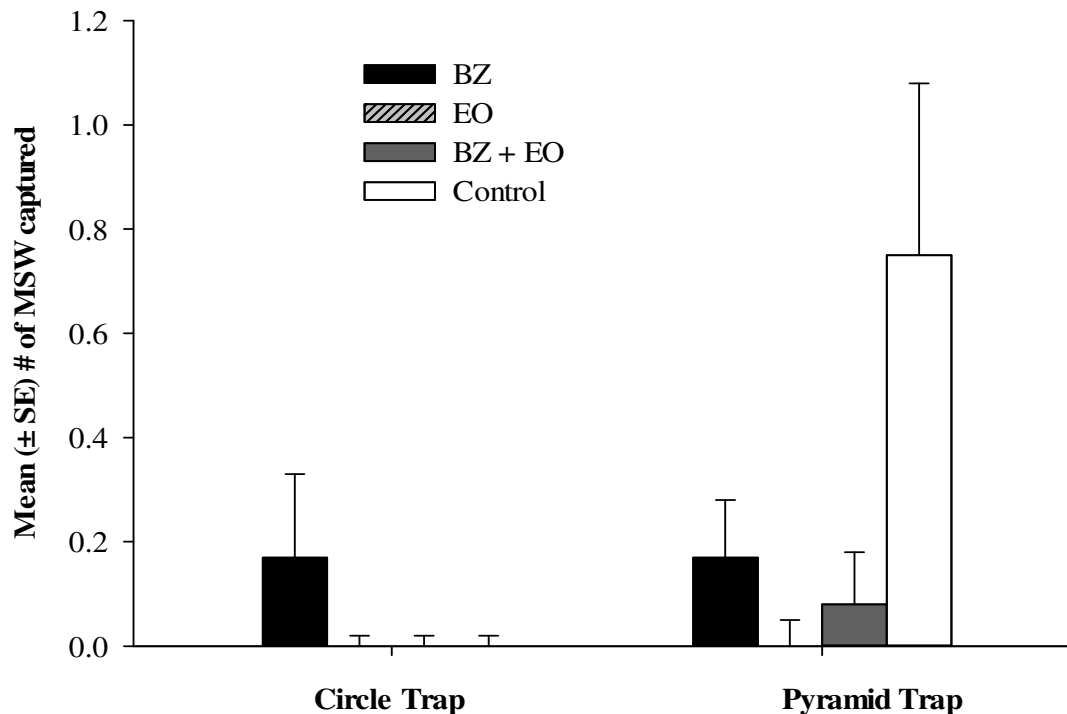


Figure 4. Mean ($\pm$ SE) of the number of mango weevils captured by the traps and lures.

The release rate of attractants

The 2.55mg/hour release rate of BZ and 2.18mg/hour of EO showed significant differences when they were determined in the field. However, no significant differences were observed when the release rates of EO (1.48mg/hour) and BZ (1.80mg/hour) were determined in the laboratory (Table 2). The volatile release of EO was found to be faster than BZ both in the field and the lab. Benzaldehyde was determined to be released at a rate of 2.55 mg/h and 1.80 mg/h in the field and laboratory respectively; whereas the volatile releases of the essential oils were found to be 2.18 mg/h in the field, and 1.48 mg/h in the laboratory (Table 2). Even though there was significant difference between the release rates from BZ and EO during the field determination; this result did not affect trap capture when the two were used as attractants in combination with the traps.

DISCUSSION

The results from this study have shown that all the

four trap types evaluated could capture the stone weevil in managed mango orchards, although the numbers were very low. Research conducted earlier showed that the black pyramid trap was superior in capturing weevils with similar ecology and biology like the stone weevil (Johnson et al., 2002; Akotsen-Mensah et al., 2010). The pyramid trap is believed to provide an attractive visual stimulus by mimicking a tree trunk (Teddars and Wood, 1994; Mulder et al., 1997). Although in the earlier trapping experiments in 2014 no attractants were added, the black pyramid trap consistently recorded the highest number of stone weevils.

The results however, indicated that the addition of the attractants did not significantly increase the trap numbers compared with the data obtained in the earlier trapping experiments without attractants. Even though we hypothesized that the addition of the attractants to the traps will improve their capture the results showed otherwise. Our selection of benzaldehyde as a potential attractant was based on literature that benzaldehyde is a major active component found in most fruits (Prokopy et al., 2000; Leskey et al., 2001) and supported by our based on our preliminary laboratory results.

Table 1. Description of the different phenological stages of the mango crop from June 2013-March 2015.

Phenology	2013	2014	2015
Fruit maturity	Jun 26–July 17	Mar 26	
Vegetative growth	Jul 24–Aug 14	Jul 7–28	Dec 22 – Jan 5
Blooming	Aug 21–Sept 18	Aug 4–Sept 1	Jan 12–Feb 9
Fruit set	Sept 25–Oct 2	Sept 8–22	Feb16–23
Fruit development	Oct 9 –Nov 27	Sept 29–Nov 10	Mar 2–Apr 27
Fruit maturity	Dec 4–Mar 26	Nov 17– Dec 15	May 11 – Jun 15

Minor season (December to February) and major season (June to August).

Table 2. Release rates of the benzaldehyde and essential oils under field (only pyramid trap) and laboratory conditions.

Treatment	Mean ($\pm$ SE) (field) mg/hour	Mean ($\pm$ SE) (Lab) mg/hour
EO	2.18 $\pm$ 0.06 b	1.48 $\pm$ 0.13
BZ	2.55 $\pm$ 0.06 a	1.80 $\pm$ 0.13 NS

BZ = commercial benzaldehyde lure; and EO = Essential oil. Means having no letter in common are significantly different (Student's t- test $P < 0.05$; $n = 5$). NS means not significant.

As a result it was hypothesized that the mango stone weevil could be attracted to this ubiquitous (found in many fruits particularly during ripening) compound. As already indicated, the results from this study did not provide enough evidence to support this hypothesis although preliminary investigations in the laboratory had provided some evidence of the weevil being marginally attracted to benzaldehyde. The results of adding the attractants in association with the traps did not provide the evidence that mango stone weevil could either be attracted to single components of benzaldehyde or essential oil from the mango inflorescence or their combinations. Black pyramid and Circle traps with lures (benzaldehyde, grandisoic acid and plum essence) evaluated by Akotsen-Mensah et al., (2010), in Alabama peaches revealed a significant increase in trap capture in the number of plum curculios. Leskey and Wright (2004a) also found that plum curculios were only attracted to traps baited with aggregation pheromone and benzaldehyde in apples. It was reported that the mango stone weevil prefers the reproductive (flower) part of the mango plant to other parts in a research conducted by Braimah and Van Emden

(2010) with arena and olfactometer bioassays. Even though these traps have been reported to have some appreciable captures for the plum curculio and the pecan weevil in other cropping systems, results from this work proved otherwise probably because there could be some abiotic factors which influenced the stone weevils in the tropics compared with the other related species like plum curculio and the pecan weevil which are mainly found in the temperate zone.

The performance of both the Circle and the pyramid traps in all the three study locations did not show significant difference in mean trap capture. Even though the mango orchard at Kpong recorded the highest trap captures for both circle and pyramid traps, weevil numbers were very low and far below expectation. One major possibility for the poor performance of the traps in this work was probably due to the fact that all three locations where the research was conducted were managed intensively with insecticides particularly during 2014-2015 where some of the farmers observed from the previous year's trapping work that the weevils were present in their farms. These orchards were managed with intensive spraying activities as the

most dominant strategy for the mango stone weevil. It was observed throughout the study period that anytime these orchards were visited, there was spraying activities being carried out by the farmers even though they claimed spraying was done between 3-6 times in a fruiting season. Spraying has been observed to hinder the movements of the mango stone weevils and reduce their activities (Personal communication).

In Somanya where there was no trap capture in 2014-2015 with attractants, it was observed that the farmer had introduced *Oecophylla longinoda* (Latreille) (red weaver ants) which invaded more than 70% of the mango trees as a control strategy in addition to the use of chemicals. Braimah and van Emden (2010) reported that, *Oecophylla longinoda* and *Oecophylla smaragdina* (Fabricius) were the most promising indigenous generalist predators of the mango stone weevil. This probably accounted for the zero trap capture in Somanya even when the attractants were present. Another possibility for the poor performance of the traps may be due to the generally low populations of mango stone weevils in the study areas. In a research conducted by Leskey et al., (2005) on non-fruiting host tree volatile blends as novel attractants for the plum curculio, it was found that an increased population density of plum curculios accounted for higher trap captures. Research has shown that volatiles released by host plants were as attractive as single fruit-based synthetic attractants (Leskey et al., 2005). Therefore it was possible that the volatiles from the mango plant competed with the attractant thus resulting in few adults being captured in the traps. The volatile release of benzaldehyde and other compounds by host trees contributed to reduction of plum curculio captures in benzaldehyde baited traps when in close proximity to host trees (Leskey and Wright, 2004b). This probably accounted for the inability of the essential oils in combination with the Circle and pyramid traps to capture any mango stone weevil throughout the study period. Essential oils was also extracted from mango flowers, and thus, the degree of competition from natural sources of olfactory stimuli, that is, host mango trees, will likely be greater if baited traps are deployed within a mango orchard. Also, the essential oil did not work perhaps because it was a crude extract. Crude extracts have various components; some of which may either be attractants or repellents (Mathew et al., 2009). It has been established that insects captured by the

pyramid traps could escape from the trap tops especially if regular monitoring was not carried out. Hogmire and Leskey (2006) reported that the black pyramid traps recorded very low trap captures due to escape of stink bugs from the pyramid traps in a research conducted to monitor stink bugs in apple and peach orchards in West Virginia. In this work, trap monitoring was done every week (2013-2014) and every two weeks (2014-2015); within which stone weevils captured by the pyramid traps may have escaped from the traps and probably accounted for the number of weevils recorded in the pyramid traps. Indeed a preliminary tested found out that when temperatures were high weevils could escape from the trap in 48 hours.

In conclusion, even with addition of the lures, the traps still recorded very low number of mango stone weevils far below expectation in this research. Of the two trap types evaluated, the pyramid trap performed better by capturing more of the stone weevils compared to the Circle trap in all the three study areas. Intensive spraying of the orchards, low stone weevil populations, high concentrations of host plant volatiles released in the orchards were some of the possible reasons for the low numbers of stone weevils captured by the traps. The possibility of the stone weevils to escape from the pyramid traps, and the fact that the essential oils used in this work was probably a crude extract; may have also accounted for the poor performance of the traps and the very low mango stone weevil numbers recorded in this research. Analytical and electrophysiological studies will be carried out on the essential oil to identify biological active compounds for future use in managing the stone weevil in Ghana.

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