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Pollinator management and insecticide usage within cocoa agroecosystem in Ghana

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ABSTRACT

Ghana being a leading cocoa producer, depends heavily on pesticides although the crop is strictly entomophilous, primarily pollinated by ceratopogonid midges. This study in Ghana, investigated impact of confidor 200SL (Imidacloprid) and aqueous neem seed extract (ANSE) insecticides on abundance of pollinators and fruit-set in cocoa Three pollinator sampling methods (motorized aspirator, pan and McPhail traps) were used. Results show significantly more abundant midges on ANSE treated farms compared to confidor treated farms, 2 ($t = 4.34$; df = 69; $P < 0.001$) and 60 – 120 ($t = 1.85$; df = 39; $P < 0.041$) days after spraying insecticides (DASI). Midge population recovered within 30 DASI under both insecticide treatments culminating in comparable abundance over this period. Fruit-sets within 30 DASI were however significantly higher indicating that fruit-set is affected though midge population recovered. Although both insecticides were deleterious to the midges, ANSE was lesser and therefore preferred to confidor. This result show both insecticides did not discriminate against beneficial insects, hence it will be important to consider a more comprehensive approach to the study of managing insect fauna complex within cocoa agroecosystem.

KEYWORDS

Ceratopogonid midges;
Cocoa;
Insecticide;
Neem;
Fruit-set;
Pollinators.

INTRODUCTION

The synchronous population dynamics of the major cocoa pests (mirids) and pollinators (ceratopogonid midges), particularly in West Africa which accounts for over 70% of global production of the crop, poses great challenge in managing cocoa farms. Failure or inefficient pest control will lead to heavy loss especially where a mean of 6 mirids per 10 trees is considered economically injurious[20]. Mirid population peaks from August – September and may be sustained until December[16]. A second peak usually occurs in February[16] but efficient management in August – December may prevent the second population surge[8,18]. Population of cocoa pollinating midges also builds up from April, reaching its peak in June – August, and least abundance occurs in December – March[10,14,24].

The first flower bloom of cocoa occurs between February and April depending on the rainfall. This period coincides with the lowest midge population which limits pollination at this critical period. A second peak of bloom occurs in June – July but reduces drastically from August, at the time that pollinators abound[11,24,27,29]. Base on the mirid population dynamics, August to December have been determined to be the most appropriate period to control the pests with insecticides and this regime possibly could have adverse effect on the pollinators. Available data on insecticide – midge interaction is scanty, and where available they are mostly on insecticides obsolete to cocoa production, leaving researchers and policy makers to only extrapolate. It is therefore imperative to assess pollinator populations under current production conditions.

Ghana currently undertakes mass spraying of cocoa farms through the Cocoa Diseases and Pest Control (CODAPEC) programme from August – December[1,3]. This prophylactic application of synthetic insecticides on cocoa has been criticized by Leston[16] due to possible effect on beneficial insects. Integrated approaches like biological control[4,15,20] symptomatic or 'spot' chemical application[18,23], botanical insecticide usage[4,15,21] and pheromone traps[4] have been suggested as alternatives. Managing mirids below the economic threshold by a single non-chemical method, however, looks gloomy[6] and thus combination of neem, biological and pheromone traps have been recommended[4]. The use of neem may however affect the mirids as well as beneficial insects including parasitoids, predators and pollinators. More studies will therefore be required in the management of the insect fauna with neem products within the cocoa agroecosystem.

Studies on the use of neem have extensively focused on its pest control efficacy without a critical look at its effects on beneficial insects, particularly pollinators. The high prospects of neem in integrated management of cocoa pests makes it ideal candidate whose effect on cocoa pollinators must be investigated in addition to evaluation of its pests control efficacy. This study, therefore, assessed the effect of a synthetic insecticide, confidor 200SL (Imidacloprid) used in CODAPEC mass spraying and botanical insecticide, Aqueous Neem Seed Extract (ANSE) on cocoa pollinators.

MATERIALS AND METHODS

Study areas

The study was conducted in 18 cocoa farms, selected from three cocoa growing regions in Ghana: Kubease-Wuraponso (Ejisu-Juabeng District, Ashanti Region), Abrafo-Ebekawopa (Twifo Heman Lower Denkyira District, Central Region) and Edwenease (Mpohor Wassa East District, Western Region). Six cocoa farms of varying sizes (1.6 – 4.0ha) and mixed varieties of Upper Amazonia and CRIG hybrids were selected from each region.

Application of insecticides

Insecticide spraying was designed to conform to the CODAPEC mass spraying. Three farms from each growing region were randomly selected and sprayed with confidor 200SL while the other three farms were sprayed with ANSE. Recommended application dosage of 150ml/ha (60ml/acre) of confidor 200SL was used in the selected farms[1]. A 20%w/v ANSE was prepared by adding water to 20kg of grounded neem seeds to attain 100 liters. Mixture was stirred thoroughly and allowed to stand for 24 h before sieving off the debris[2,26]. Farms earmarked for ANSE application were treated at a rate of 100L/ha (Cudjoe, A.R., CRIG, 2007: personal communication) after 17 00 hours, to prevent the main active ingredient of neem (Azadirachtin) from breaking down by sunlight. For uniformity, confidor was also sprayed at 3 – 5 pm. The T2 spraying method, where two opposite sides of cocoa trees are sprayed, was employed using motorized mistblower[8]. Both insecticides were applied monthly from September to December 2008.

Experimental design and sampling methods

Smaller cocoa farms (1.6 – 2.4ha) were divided into four quadrants, each quadrant having mean area (±SD) of 0.5±0.1ha: only 2.0ha portion of larger farms (2.5 – 4.0ha) were divided for sampling although entire farms were sprayed. Abundance of midges and cocoa fruit-set were sampled using the three complementary methods, described by Frimpong et al.[11], outlined below from September 2008 to April 2009:

1. **Focal tree observation and sampling with motorized aspirator:** One cocoa tree with open flowers was selected from each quadrant and experimental trees per sampling day were changed depending on the availability of flowers. One meter section (0.3m from the soil) of the trunk of experimental tree per quadrant was marked with indelible ink. All insects visiting open cocoa flowers within the marked section over 10 minute period were

collected using motorized aspirator on the 2nd and 30th days after application of insecticides (DASI) from September (last week of the month) to December. Flower sampling continued at 60, 90 and 120 days after the last insecticide spraying in December, to assess the residual effect of the insecticides on the pollinators. All insects (except lepidopterans) trapped were stored in 70% ethanol for later identification in the laboratory. Some specimens were sent for barcoding due to identification difficulties. However, specimens could only be identified to the family level (www.boldsystems.org/views/taxbrowser.php?taxid=567).

2. **UV-bright painted pan traps (UVPPT) and McPhail traps:** A set of yellow, blue and white UVPPT were filled to three-quarters (3/4) full with soapy water and hung in the canopy of another marked cocoa tree (different from those in focal tree set up) on each quadrant. On a third cocoa tree within each quadrant, a McPhail trap was also set up. UVPPT and McPhail traps were set soon after spraying and allowed to stay in the canopy for 2 days (approximately 48 hours). Traps were set at 2, 30 DASI from September to December as well as 60, 90 and 120 days after the last spraying in December.
3. **Fruit-set:** *Another cocoa tree (different from trees u*sed in the pollinator sampling) was randomly selected from each plot and 0.3 – 1.3m section of the trunk, measured from the soil, was marked[22]. All open flowers, cherelles and pods within the marked sections were excised on the first month (September) of sampling. All flower buds, open flowers, cherelles (including wilted) and pods in the marked sections were counted monthly (30, 60, 90 and 120). New cherelles were marked with indelible ink whiles wilted cherelles and ripe pods were excised on each sampling day. Cocoa bud takes 28 days to open fully[25] and drops *after appro*ximately 2 days if not pollinated[17] and it was therefore assumed that counted buds would have opened and been pollinated within the 30 days sampling intervals. The percent fruit-set F_s within marked sections at 30, 60, 90 and 120 DASI were calculated as[10]:

$$F_s = \frac{[(C_u + C_w + P_u + P_r)\ (C_m + P_u)]}{F_b + F_o} \times 100$$

Where C_u, unmarked cherelles for the month; C_w, wilted cherelles; P_u, unripe pods; P_r, ripe pods; C_m, previous months' cherelles; P_u, unripe pods; F_b. 95% of flower buds [according to McKelvie[17], estimated 95% of flower buds become open flowers]; F_o, open flowers of the previous month

Analyses of data

Statistical analysis covered only the major pollinators, midges, because of their shear abundance relative to other pollinators and also observation of a strong positive correlation between the midges and fruit-set of cocoa[10]. Normality and homogeneity of insect counts and cocoa fruit-set were evaluated by plotting scatter diagrams of means against variances[12]. Data were then transformed to $\sqrt{(X+0.5)}$ before Student t-test was used to compare the effect of the two insecticides using Minitab 13.3. Data were back-transformed before interpreting them.

RESULTS

Conventionally acclaimed prime pollinators of cocoa, midges were the predominant pollinators beside minors such as cecydomyiids, ants, *Hypotrigona (Liotrigona)* (stingless bee whose pollination status is unconfirmed; Frimpong et al.[11]). Results and discussions presented here pertain to only the ceratopogonid midges.

Generally, the numbers of midges and cocoa fruit-set in farms treated with ANSE were higher than the confidor treated farms in all sampling intervals (2, 60, 90 and 120 DASI) except at 30 DASI where midge abundance were similar (Figure 1). The differences between the two insecticide treatments at 2 DASI (t = 4.34; df = 69; P < 0.001) and 60 – 120 DASI (t = 1.85; df = 39; P < 0.041) were significant. populations at 30 DASI were only marginally higher (t = 1.00; df = 67; P > 0.321) in farms treated with ANSE (13.86 ± 0.23) compared to that in confidor treated farms (11.75 ± 0.19) (Figure 1b). However, fruit-sets in farms sprayed with ANSE (2.97 ± 0.16%) and confidor (2.20 ± 0.13%) at 30 DASI differed significantly (t =1.06; df = 63; P < 0.001) (Figure 1b). The fruit-set of 1.26 ± 0.04% and 0.66 ± 0.06% recorded in ANSE and confidor treated farms respectively at 60 – 120 DASI shows the former is significantly higher (t = 3.60; df = 52, P < 0.001).

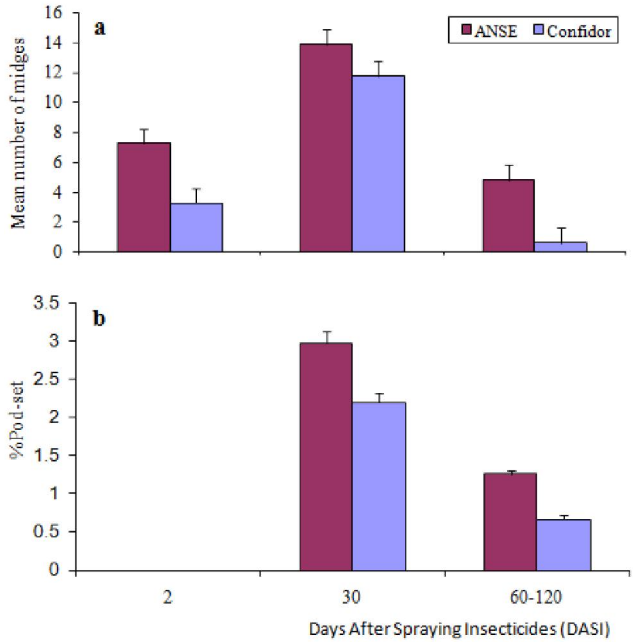

Figure 1 : a) Mean (±SE) number of ceratopogonid midges and b) Mean (±SE) percent fruit-set of cocoa 2, 30 and 60 – 120 days after spraying cocoa farms with confidor and ANSE..

Midge populations recorded 2 days after spraying ANSE and confidor generally decreased consecutively from the first spraying in September through the last in December (Figure 2). Both the number of midges and cocoa fruit-set at 30 DASI (October – December) and 60 – 120 days post spraying period (January – April) also decreased in subsequent months, reaching their lowest in February – March after the effect of dryness had peaked in January and March (Figure 3). The graphical presentation (Figures 2 and 3) also show general trends of higher numbers of midges and fruit-set in ANSE treated farms than confidor over the months in all the sampling intervals.

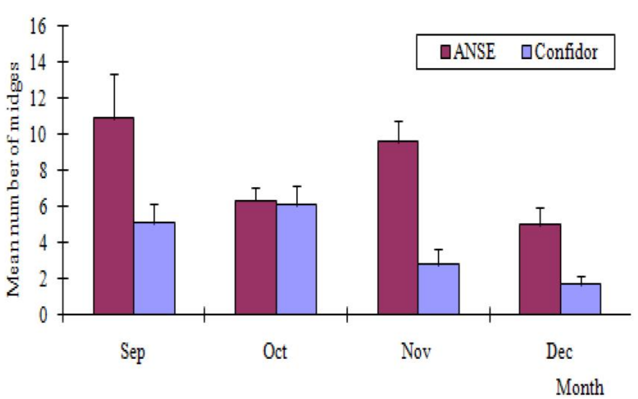

Figure 2 : Monthly mean (±SE) number of ceratopogonid midges 2 days after spraying cocoa farms with ANSE and confidor insecticides (monthly applications, September - December).

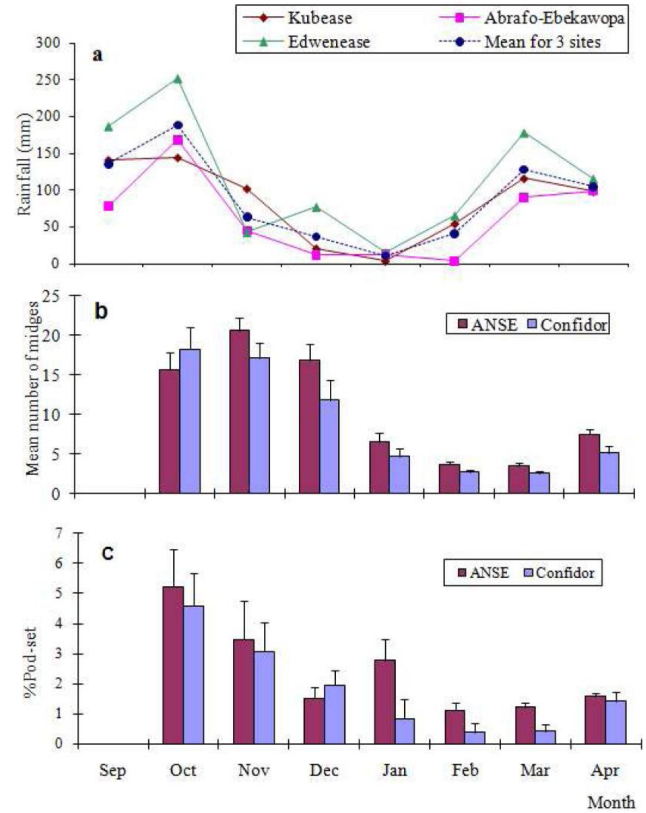

Figure 3 : a) Monthly rainfall in relation to b) Mean (±SE) number of ceratopogonid midge population and c) Mean (±SE) percent pod of cocoa.

DISCUSSION

Our study highlights the possible impact of insecticides on populations of the main cocoa pollinators, midges and consequently fruit-set. Cocoa obligatorily requires insect pollinators for cross pollination whether self–incompatible or self-compatible[7,9]. This means management practices, such as gratuitous insecticide application, which tend to limit the abundance of the prime pollinators will affect fruit-set and subsequent yield of cocoa.

We observed that both ANSE and confidor insecticides reduced midge populations as well as cocoa fruit-sets but to different extents. This is apparent from the outcome where lesser numbers of midges were recorded at 2 DASI compared to 30 DASI, throughout the spraying months (September – December), under both insecticide treatments. For example, while the mean number of midges at 2 DASI were 7.3 and 3.3 in farms treated with ANSE and confidor respectively, 13.7 and 11.8 respectively were recorded 30 DASI. Confidor, however, was generally more deleterious to midges than ANSE as lower numbers of the pollinators and fruit-set was observed in farms treated with the former insecticide.

The higher number of midges and fruit-set at 30 DASI compared to that at 2 DASI in both treatments also implies the midge populations were able to recover within 30 days after spraying. This recovery may have been facilitated by provision of better breeding conditions from September through November. Midges breed in rotting organic substrates whose availability depends on rainfall[14,29]. This notwithstanding, the significantly lower midge populations recorded 2 days after spraying confidor and ANSE, and marginally lower numbers at 30 DASI imply a higher recovery in the former insecticides. Thus confidor had higher direct mortality effect on adult midges while the ANSE probably has more adverse effect on the immature forms than confidor. Deducing from the 21 days egg – adult development span for midges[13,14], immature forms of midges probably recovered close to 30 DASI (ie after 21 DASI) and therefore could not effect significant pollination before the farms were sprayed again. The significantly higher fruit-set recorded 30 days after spraying ANSE could therefore be attributed to relatively lower spontaneous mortality (2 DASI) on adult midges, compared to confidor. Thus relatively smaller proportion of the stock population was eliminated by ANSE at each spraying and this resulted in higher pollinator abundance in these farms for greater part of the month, compared to confidor.

Confidor also exhibited longer residual effect on the pollinators than ANSE because lower numbers of midges and fruit-sets were observed under confidor at 60 – 120 DASI than ANSE. Two factors, insecticides and dry weather conditions, accounts for the least pollinator populations in February and March, and their additive effect inhibited the recovery of midges from January through March. Drying up of breeding substrates naturally reduces numbers of both immature and adult midges in the dry season[14,28]. This suggest that the December spraying should be carried out at early part of the month, as this will allow substantial recovery of the pollinators (as was observed in rainy months) before the onset of the dry season. Moreover, there will be relatively higher stock of pollinator populations at the transition from dry to rainy season (March – April) to replenish the depleted populations required to pollinate the high numbers of flowers produced at this period. It must be emphasized that the transition from dry to rainy season marks one of the peak flower bloom of the crop.

CONCLUSION

Applying both confidor 200SL (Imidacloprid) and Aqueous Neem Seed Extract (ANSE) insecticides in cocoa ecosystems influenced pollination services of the crop. Confidor was more deleterious to the midges hence reduced cocoa fruit-set to a greater extent compared to ANSE. This paper is therefore advocating for a more comprehensive approach to the study of the insect fauna complex within cocoa agroecosystem with regards to the management of both pests and beneficial insects.

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ABBREVIATIONS

CODAPEC	: Cocoa Diseases and Pest Control
ANSE	: Aqueous Neem Seed Extract
DASI	: Days After Spraying Insecticide

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