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Farmers' knowledge and practices on pollination and insecticide use in cocoa farming in Ghana

Blessing C. Umeh^a, Silas W. Avicor^b, Enock Dankyi^c and Rosina Kyerematen^d

^aAfrican Regional Postgraduate Programme in Insect Science, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana; ^bEntomology Division, Cocoa Research Institute of Ghana, New Tafo-Akim, Ghana ; ^cDepartment of Chemistry, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana; ^dDepartment of Animal Biology and Conservation Science, College of Basic and Applied Sciences, University of Ghana, Legon, Ghana

ABSTRACT

Although evidence of the limiting role of pollination in cocoa production is mounting, concern about the potential harm of insecticides to pollinators is also increasing. However, effort at examining farmer knowledge and practices on pollination and insecticide use aimed at promoting cocoa pollination is limited. This study assessed farmers' knowledge and practices on pollination and insecticide usage in four cocoa-growing communities (two organic and two conventional) in the Eastern region of Ghana. Data from interviewing cocoa farmers (200) with a structured questionnaire were analysed using various statistical techniques. Less than 50% of the farmers had knowledge of pollination and its influence on yield. Only 1% of the respondents identified midges as pollinators of cocoa, while 11% and 19.5% identified honey bees and ants as pollinator agents, respectively. Less than 50% of respondents believed insecticide application might impact on beneficial insects, including pollinators. Farmers' responses were highly influenced by farming system, educational background, farmer groups and extension officers. Our findings show that educating smallholder farmers on pollination and judicious insecticide use is crucial in improving long-term cocoa yields. These findings have implications for pest management policies and farmer sensitization on the impact of indiscriminate insecticide application on the environment and pollinators.

KEYWORDS


Cocoa farming; cocoa pollination; farming systems; insecticides; midges; Ghana

1. Introduction

Cocoa is a major export commodity of considerable importance to many smallholder farmers in West Africa (Ndubuto et al., 2010). In Ghana, the cocoa sector is a major source of income for about 800,000 families (Anim-Kwapong & Frimpong, 2004; Maguire-Rajpaul et al., 2020) and an important foreign exchange earner for the country. Given the crucial role of cocoa to the economy, the government of Ghana, through the Ghana Cocoa Board (COCOBOD), introduced a national Cocoa Disease and Pest Control (CODAPEC) programme in the 2001/2002 season to mass spray insecticides and fungicides directly on cocoa farms or make these

pesticides available to farmers at no direct financial cost (Dormon et al., 2004). This mass application programme has helped significantly improve cocoa yields while also helping to curb the use of unapproved pesticides on farms. Nonetheless, the programme has been associated with the misuse and abuse of pesticides, perhaps spurred by the zero direct cost and ready availability to farmers. A survey by Antwi-Agyakwa et al. (2015) showed that the rate of application of recommended insecticides by farmers was considerably higher than COCOBOD's recommendation. This misuse of pesticides poses substantial threats to the environment and non-target organisms such as pollinators (Rodger et al., 2004). Studies show

CONTACT Silas W. Avicor  wintuma@live.com  Entomology Division, Cocoa Research Institute of Ghana, P. O. Box 8, New Tafo-Akim, Eastern Region, Ghana

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that the value of ecosystem services such as pollination to agriculture is significant but largely undervalued in cocoa ecosystems (Evans et al., 2011; Power, 2010; Toledo-Hernández et al., 2017). Pollination is crucial to cocoa production, and insects primarily pollinate the cocoa tree. Pollination exclusion tests by Adjaloo (2012) and Kaufmann (1975) showed that cocoa is strictly entomophilous; thus, the importance of insect pollinators as an effective strategy in ensuring high cocoa yield.

Several studies have outlined the impact of pesticide application on the status, abundance and diversity of beneficial organisms such as midges, the major pollinators in cocoa agroecosystems (Frimpong et al., 2009; Sabatier et al., 2013; Toledo-Hernández et al., 2017). These pesticides may cause mortality by direct intoxication, which leads to pollinator diversity displacement and may decrease pollinators' abundance by indirectly decreasing floral resource availability (Alston et al., 2007; Gabriel & Tscharnkte, 2007). A recent study in Côte d'Ivoire showed that habitat destruction through unsustainable pest management practices such as insecticide misuse reduced the overall population of pollinators, subsequently affecting pollination services for cocoa trees (Claus et al., 2018). Multiple human-induced factors, such as pesticides, introduced pathogens, global warming, and land-use change have been associated with declines in insect pollinators (Novais et al., 2016). Motivations that incentivise pesticide use can hinder farmer adoption and transition to ecologically sound and sustainable agricultural systems (Zakowski & Mace, 2022).

Farmers play a crucial role in influencing some of these factors, including pollinator abundance and diversity. Thus, understanding farmers' knowledge of pollination, biodiversity and the farm practices employed to boost biodiversity is essential in promoting ecosystem services in cocoa production. Quite clearly, improving sustainable agroecosystem services would involve proper agricultural practices and management, which relies on farmer's knowledge. However, such studies on farmer knowledge and practices on pollination and other ecosystem services are lacking, particularly in the sub-region and cocoa production. This study sought to address this knowledge gap by promoting better agricultural practices that protect biodiversity and improve ecosystem services for sustainable cocoa production through reducing indiscriminate insecticide application practices in its cultivation.

2. Methods

2.1. Study area

The survey was carried out in four communities comprising two organic cocoa-growing communities: Aponoapono and Kookoo-Ano, in the Suhum Municipal Assembly, and two conventional cocoa-growing communities: Addo-Nkwanta and Obopekonya, in the Abuakwa North Municipal Assembly. All four communities are located in the Eastern region of Ghana, with the conventional farms located at least 20 km away from the organic farms. The region was selected due to its location in the semi-deciduous rainforest zone of the country, with a moderate climate and vegetation. It is also Ghana's oldest cocoa-growing area and one of the regions with the most organic cocoa farms (Abenyega & Gockowski, 2001).

2.2. Data collection

We conducted face-to-face interviews with farmers using structured questionnaires between February to May 2020. Informed consent was sought from farmers before the questionnaires were administered, and thereafter, the data collected was anonymized. A pre-test structured questionnaire was used for piloting to assess ambiguities in the questions. This trial was conducted among 20 farmers at Kokotesua near Kookoo-Ano, one of the selected communities. A total of 200 cocoa farmers were interviewed during the main survey with the aid of the refined structured questionnaires. Farmers in each community were randomly selected from a list of farmers obtained from heads of farmer associations and extension officers of the District Offices of the Cocoa Health and Extension Division (CHED), a subsidiary of COCOBOD. The sample size was obtained through random sampling from a total of about 1,100 farmers present in the four communities.

2.3. Data analysis

Responses from farmers in the various communities surveyed were analyzed to show their frequencies and percentages. Chi-square tests of homogeneity of ratios of farmer responses from the four communities were conducted to determine whether personal and farm characteristics were associated with farmers' access to information on pollination, insecticide usage and other agronomic practices. Multinomial

regression analysis was also used to explain the relationship between the cocoa production systems using the organic cocoa system as a reference category (dependent variable) and other independent variables. Spearman's correlation was performed to show relationships between some response variables and gender, age, level of education and years of experience in cocoa cultivation. Data analysis was performed using SPSS version 20.0.

3. Results

3.1. Socio-economic profile of communities surveyed

Overall, the farmers engaged in the study were predominantly male (73%), and 85.3% of the farmers were aged 36 years and above (Table 1). Based on educational level, 15.5% of farmers had no access to formal education, whereas 84.5% of farmers had obtained basic or secondary education. Among the farmers, none had access to tertiary education. Nonetheless, the level of education was significantly different among farmers in the four communities surveyed. Most respondents practised cocoa farming as their main occupation, and 87.6% of the respondents had been farming for more than five years, mostly in farmlands of more than 3 acres. The age of trees was highly variable among communities, with many of the cocoa trees above 25 years (Table 1).

Multinomial regression analysis predicted a significant relationship between the cocoa production systems practised and the socio-economic characteristics of the respondents ($F(8) = 36.470, p < .000$). The analysis showed that the age group and level of education of farmers did not significantly predict the cocoa production system practised, but the gender and age of cocoa trees however significantly predicted the cocoa production system practised (Table 2).

3.2. Agronomic practices

Almost all farmers practised intercropping in cocoa farms using plantain as the predominant crop (68.3%). In most farms, *Terminalia superba* (53.7%) or *Citrus* spp. (38.3%) was planted by the farmers as shade trees on cocoa farms. Besides the need for shade trees in cocoa production, weeds pose significant constraints to cocoa production. Consequently, at least 67.5% of the farmers reported weeding their farms manually or using herbicides at least four times each

year. As expected, weedicide application was absent in organic farming as farmer associations were firmly against using such pesticides. However, 50% of conventional cocoa farmers frequently applied weedicides in weed control (Table 3). Besides weed control, all farmers engaged in the pruning of trees on a monthly (24.2%), bi-monthly (14.1%) or less frequent basis, such as once or twice a year (61.6%).

For most farmers (59.7%), the insecticides applied on their farms were obtained from their association or group. In a bid to manage these pests, 42.7% of these respondents reported following the approved COCOBOD recommended period for spraying, which is August, September, October and December, while 42.2% of the farmers reported spraying insecticides for management of these pests once or twice a year (Table 3). Also, 10.6% of these farmers do not apply insecticides on their cocoa farms, while 59.7% of the respondents obtained insecticides applied on their farms from their farmers' associations or groups (Table 3).

While 18% of respondents from the organic cocoa-growing communities reported zero application of insecticides, the majority of farmers in this group applied pyrethrin-based insecticides only, as approved by their farmers' association. As expected, most respondents practising conventional cocoa production followed the COCOBOD recommended insecticide spray regime (Table 3). Farmers adopted different management practices to control insect pests across the communities surveyed. These include the application of insecticides such as imidacloprid (Confidor®), bifenthrin (Akate Master®), thiamethoxam (Actara®) and a bio-insecticide containing pyrethrin (AgroPy 5EW®). At the same time, some farmers adopted cultural or non-chemical methods such as intercropping, planting of shade trees, weeding and pruning to manage pests.

The results of the multinomial regression analysis were significant at ($F(13) = 220.89, p < .000$). The analysis showed that frequency of weeding, frequency of weedicide application and knowledge of mirids did not significantly predict the cocoa production system practised but were all positively associated. However, the type of weedicide used and pruning frequency significantly predicted the practised cocoa production system (Table 4).

The majority of the farmers left substrates (cocoa leaves, cocoa pod/husk, banana/plantain pseudostem) on their farms, although several farmers (10.4%) were unaware of any impacts/benefits of the

Table 1. Socio-economic characteristics of respondents in different communities.

Variable	Percentage response					Statistical analysis	
	A (CC1) (n = 50)	B (OC1) (n = 50)	C (OC2) (n = 50)	D (CC2) (n = 50)	Pooled	χ	<i>p</i> -value
Gender							
Male	70.0	68.0	86.0	68.0	73.0	5.78	0.123 ^{ns}
Female	30.0	32.0	14.0	32.0	27.0		
Age							
<18 years	0.0	0.0	2.0	0.0	0.5	26.30	0.002*
19–35 years	4.2	30.0	12.0	10.2	14.2		
36–50 years	50.0	24.0	46.0	61.2	45.2		
Above 50 years	45.8	46.0	40.0	28.6	40.1		
Level of education							
Basic education	68.0	60.0	54.0	90.0	68.0	28.25	0.00*
Secondary/vocational school	14.0	32.0	18.0	2.0	16.5		
Tertiary education	0.0	0.0	0.0	0.0	0.0		
Non-formal	18.0	8.0	28.0	8.0	15.5		
Cocoa farming as main occupation							
Yes	64.0	36.0	58.0	34.0	55.5	18.84	0.092 ^{ns}
No	36.0	34.0	42.0	66.0	44.5		
Area of land under cultivation							
<1 acre	4.1	4.0	6.0	0.0	3.5	5.60	0.468 ^{ns}
1–2 acres	30.6	28.0	32.0	20.0	27.6		
>3 acres	65.3	68.0	62.0	80.0	68.8		
Duration of cocoa cultivation							
<2 years	2.1	2.0	0.0	2.1	1.5	11.70	0.069 ^{ns}
2–5 years	8.5	14.0	20.0	0.0	10.8		
Above 5 years	89.4	33.3	80.0	97.9	87.6		
Age of cocoa trees							
1–10 years	20.0	16.3	14.0	64.0	28.6	47.99	0.00*
10–25 years	40.0	32.7	48.0	6.0	31.7		
Above 25 years	40.0	51.0	38.0	30.0	39.7		

A: Addo-Nkwanta; B: Aponoapono; C: Kookoo-Ano; D: Obopekonya. OC1: Organic cocoa community 1; OC2: Organic cocoa community 2; CC1: Conventional cocoa community 1; CC2: Conventional cocoa community 2. *: statistically significant at level 5%; ns: statistically non-significant.

substrates left on farms. For most (89.4%) farmers, the substrates were left as a source of manure, and the farmers were unaware of the role of the substrates left on the farm as breeding sites for midges (Table 5).

3.3. Knowledge of pollination

The study shows a significant difference in perceived knowledge of pollination among organic and

conventional farmers. Interestingly, conventional farmers had a higher knowledge of pollination than organic farmers (Table 5). In general, 41.8% of farmers were aware of the concept of pollination, 55.5% of farmers reported a lack of knowledge of the effect of pollination on fruit development, and 4.5% of the respondents believed pollination is not required for fruit development. As expected, 44% stated the importance of pollinators in increasing

Table 2. Relationship between the socio-economic characteristics of respondents and the cocoa production system practised.

Cocoa production system ^a		B	Std. Error	Wald	df	Sig.	Exp(B)
Conventional farming	Intercept	−3.521	1.745	4.069	1	0.044	
	Gender	0.867	0.390	4.953	1	0.026	2.380
	Age group	0.381	0.260	2.144	1	0.143	1.464
	Level of education	−0.245	0.150	2.684	1	0.101	0.783
	Main occupation	0.406	0.368	1.218	1	0.270	1.501
	Side occupation	0.374	0.111	11.347	1	0.001	1.454
	Duration of cultivation	0.227	0.384	0.349	1	0.555	1.254
	Area under cultivation	0.457	.309	2.179	1	0.140	1.579
	Age of cocoa trees	−0.868	.236	13.593	1	0.000	0.420

a. The reference category is organic farming

Table 3. Farmers' management practices in the four cocoa-farming communities.

Variable	Percentage response					Statistical test	
	A (CC1) (n = 50)	B (OC1) (n = 50)	C (OC2) (n = 50)	D (CC2) (n = 50)	Total	χ	p -value
Frequency of insecticide application							
No spray	4.1	12.0	24.0	2.0	10.6	180.02	0.00*
1 month	2.0	0.0	0.0	4.0	1.5		
Quarterly in a year	4.1	0.0	0.0	8.0	3.0		
COCOBOD recommendation	83.7	0.0	0.0	86.0	42.7		
Others	6.1	88.0	74.0	0.0	42.2		
Source of insecticide							
Approved dealer	57.1	4.0	4.7	85.7	38.7	103.90	0.00*
Farmers association	38.8	96.0	93.0	14.3	59.7		
Others	4.1	0.0	2.3	0.0	1.6		
Frequency of weeding							
Monthly	32.0	0.0	2.0	26.0	15.0	83.51	0.02*
Bi-monthly	2.0	0.0	2.0	18.0	5.5		
Quarterly in a year	48.0	36.0	50.0	54.0	47.0		
Others	18.0	64.0	46.0	2.0	32.5		
Shade trees							
<i>Citrus</i> spp	8.1	96.9	76.2	2.3	38.1	105.82	0.00*
<i>Terminalia superba</i>	73.0	3.1	14.3	93.2	53.7		
Others	18.9	0.0	9.5	4.5	8.2		
Intercrop							
Cocoyam	21.6	4.5	2.4	65.8	22.4	62.67	0.00*
Plantain	70.3	77.3	90.5	31.6	68.3		
Others	8.1	18.2	7.1	2.6	9.3		
Frequency of applying weedicides							
No spray	53.0	100.0	100.0	48.0	75.4	110.69	0.00*
Bi-monthly	38.8	0.0	0.0	52.0	22.6		
Others	8.2	0.0	0.0	0.0	2.0		
Type of weedicides							
Roundup (Glyphosate)	54.5	0.0	0.0	63.4	60.3	3.89	0.273 ^{ns}
Gramoxone (Paraquat)	18.2	0.0	0.0	12.2	14.3		
Atrazine	13.6	0.0	0.0	22.0	19.0		
Others	13.6	0.0	0.0	2.4	6.3		
Frequency of pruning							
Monthly	56.2	0.0	0.0	42.0	24.2	123.41	0.00*
Bi-monthly	8.3	2.0	6.0	40.0	14.1		
Others	35.4	98.0	94.0	18.0	61.6		

A: Addo-Nkwanta; B: Aponoapono; C: Kookoo-Ano; D: Obopokonya. OC1: Organic cocoa community 1; OC2: Organic cocoa community 2; CC1: Conventional cocoa community 1; CC2: Conventional cocoa community 2. *: statistically significant at level 5%; ns: statistically non-significant.

cocoa yield, with 47% of farmers expressing that hand pollination is a means by which farmers can influence pollination (Table 5). The 41.8% who were knowledgeable in pollination indicated extension agents as their source of information on pollination.

Most farmers who had an understanding of pollination acknowledged the fact that pollination was an important yield factor (Table 5), with about 34.5% of the farmers being aware that unpollinated flowers dropped when pollination of the flower was unsuccessful. Most farmers (62.5%) declared no knowledge of pollinator agents in the cocoa ecosystem. Out of the respondents aware of pollination,

19.5% and 11% of them identified ants (*Pheidole megacephala*) and bees (*Apis mellifera*), respectively, as cocoa pollinators. Most of the farmers were unaware of the role of midges in pollinating cocoa.

Results from the multinomial regression analysis were significant at ($F(9)=205.05$, $P<.000$). The results showed that knowledge of pollination and source of knowledge of pollination did not significantly predict but were negatively associated with the cocoa production system practised (Table 6). Other variables like pollination influenced yield and pollinators are essential significantly predicted the cocoa production system practised.

Table 4. Relationship between the agronomic practices of respondents and the cocoa production system practised.

Cocoa production system ^a		B	Std. Error	Wald	df	Sig.	Exp(B)
Conventional farming	Intercept	96.010	1032.167	.009	1	0.926	
	Method of insecticide spray	0.605	0.382	2.504	1	0.114	1.831
	Frequency of weeding	0.230	0.786	0.085	1	0.770	1.258
	Type of weedicide	-22.296	0.000	0.002	1	0.000	2.074E-010
	Frequency of pruning	-3.734	1.190	9.850	1	0.002	0.024
	Frequency of applying weedicides	15.287	1032.153	0.000	1	0.988	4.090
	Cropping system	1.505	1.078	1.948	1	0.163	4.505
	Shade trees	1.928	0.606	10.111	1	0.001	6.877
	Name of intercrop	-0.073	0.812	0.008	1	0.928	0.929
	Knowledge of mirids	0.702	1.531	0.210	1	0.647	2.017
	Period of severe mirid infestation	-1.982	0.690	8.247	1	0.004	0.138
	Source of pesticide	-2.636	0.964	7.473	1	0.006	0.072
	Time for insecticide spray	1.656	.654	6.414	1	0.011	5.240

a. The reference category is organic farming

3.4. Knowledge of the impact of insecticides sprayed on the environment

Furthermore, 89.9% of farmers claimed to know one of the key insect pests of cocoa, mirids, and 50.3% of the farmers reported August to December as the time of the year when mirid infestation was severe (Table 7). However, 34.6% of the respondents reported the peak of mirid infestation between January to April, and 51.8% reported that the insecticides sprayed had no impact on beneficial organisms, while 52.3% of the farmers reported not knowing the impact of these insecticides on the population of pollinators (Table 7).

Results from the multinomial regression analysis were significant at ($F(3) = 193.14, p < .000$), indicating that reasons substrates are left and knowledge of the impact of insecticide sprayed on pollinators did not significantly predict the cocoa production system practised (Table 8). In contrast, other variables like impact on beneficial insects significantly predicted the cocoa production system practised.

Table 9 shows the results of Spearman's correlation test between response variables against age, gender, level of education, and years of experience. It revealed a statistically significant positive correlation between age and level of education on knowledge of insect pollinators of cocoa and level of education on why farmers left cocoa substrates on their farms. There was also a statistically significant negative correlation between gender and the frequency of pruning. Furthermore, a significant correlation existed between age and timing of insecticide application as well as age and frequency of weeding. The correlation between years of experience and frequency of applying insecticides was also statistically significant.

4. Discussion

4.1. Agronomic practices

This study showed that 47% of the farmers weeded their cocoa farms manually at least three times a year. Weeds are a major constraint in cocoa production, and the application of herbicides in cocoa cultivation has been proven to reduce management costs of weeding and support better plant growth (Konlan et al., 2019). Manual weeding was identified as the major means of managing weeds, with about 75.4% of the surveyed communities weeding manually but instead of spraying weedicides on their farms.

As expected, weedicide application was absent in organic farming as farmer associations were strongly against the use of weedicides, outlining its impact on farm-level productivity and on residue levels of pesticides on cocoa. Although COCOBOD bans the use of weedicides in cocoa farms, some farmers in this study used them to reduce the management cost of hiring manual labour to weed their farms. Out of those who sprayed weedicides in the conventional cocoa-producing communities, 60.3% sprayed glyphosate-based weedicides; as indicated in Swanzy et al., (2019) that farmers relied on this weedicide to reduce the cost of hiring manual labour, which further puts a constraint on cocoa production. Some of these glyphosate weedicides have been reported to negatively impact beneficial insects, such as causing bee mortality under laboratory conditions (Abraham et al., 2018) and also affecting the diversity of bees in Ghana (Kwapong et al., 2017). Farmers who practised conventional cocoa farming relied on its use because their farmers' associations did not advise against its use.

Table 5. Awareness of pollination by farmers in the four cocoa communities.

Variable	Percentage response				Total	Statistical test	
	A (CC1) (n = 50)	B (OC1) (n = 50)	C (OC2) (n = 50)	D (CC2) (n = 50)		χ	<i>p</i> -value
Knowledge of pollination							
Yes	77.1	2.9	2.3	94.1	41.8	104.88	0.00*
Source of knowledge of pollination							
Through extension officers	97.4	100.0	100.0	100.0	98.9	1.331	0.722 ^{ns}
School/literature	0.0	0.0	0.0	0.0	0.0		
Personal observation	0.0	0.0	0.0	0.0	0.0		
Indigenous knowledge	2.6	0.0	0.0	0.0	1.1		
Pollination influences yield							
Yes	74.3	8.8	2.4	91.2	44.1	32.078	0.00*
No	2.9	0.0	0.0	2.9	1.5		
Don't know	22.9	91.2	97.6	5.9	54.4		
Flower yield fruits without pollination							
Yes	57.1	5.9	2.4	2.4	40.0	107.18	0.00*
No	14.3	0.0	0.0	0.0	4.5		
Don't know	28.6	94.1	97.6	97.6	55.5		
The fate of the un-pollinated flower							
Drop	51.4	0.0	0.0	85.3	34.5	95.344	0.00*
Unaffected	17.1	8.8	7.0	5.9	11.0		
Don't know	31.4	91.2	93.0	8.8	54.5		
Farmers can influence pollination							
Yes	62.9	29.4	23.3	82.4	49.5	49.96	0.00*
No	14.3	0.0	2.3	5.9	6.5		
Don't know	22.9	70.6	74.4	11.8	44.0		
How farmers influence pollination							
Hand pollination	37.1	44.1	34.9	82.4	47.0	62.72	0.00*
Insecticide spray	37.1	0.0	0.0	2.9	10.0		
Don't know	25.7	55.9	65.1	14.7	43.0		
Cocoa pollinators identified by farmers							
Midges (<i>Forcipomyia</i> spp.)	2.0	0.0	0.0	2.0	1.0	142.87	0.00*
Honey bees (<i>Apis mellifera</i>)	22.0	0.0	0.0	22.0	11.0		
Ants	36.0	2.0	4.0	36.0	19.5		
Others	10.0	0.0	4.0	10.0	6.0		
Don't know	30.0	98.0	92.0	30	62.5		
Pollinators are important							
Increase yield	68.6	5.9	0.0	94.1	44.0	105.86	0.00*
Affect pollination	2.9	0.0	0.0	0.0	0.5		
Not important due to self-pollination	2.9	0.0	2.3	0.0	1.0		
Don't know	25.7	94.1	97.7	5.9	54.5		
Reasons substrates are left							
Midges breeding site	2.0	0.0	0.0	0.0	0.5	10.88	0.12 ^{ns}
Harbour vector of black pod	0.0	0.0	0.0	0.0	0.0		
Fertilizer	97.1	85.3	76.7	97.1	89.4		
Don't know	2.9	14.7	23.3	2.9	10.4		

A: Addo-Nkwanta; B: Aponoapono; C: Kookoo-Ano; D: Obopekonya. OC1: Organic cocoa community 1; OC2: Organic cocoa community 2; CC1: Conventional cocoa community 1; CC2: Conventional cocoa community 2. *: statistically significant at level 5%; ns: statistically non-significant.

Drought is one of the contributory climate change effects expected to negatively affect agricultural production while leading to lower climate suitability for cocoa production. Different types of climate change adaptation strategies, such as planting shade trees to help curb the effect of climate change on cocoa production, have been adopted. Results from this study show that majority of the cocoa farmers had *T. superba* as shade trees and understood their role

in enhancing soil fertility in the cocoa agroecosystem. This correlates with studies by Graefe et al. (2017) and Blaser et al. (2017) that farmers know the importance of shade trees on cocoa productivity. This is also why resource-poor cocoa farmers in West Africa are known to intentionally retain suitable trees to provide shade for young cocoa trees during land preparation (Annani-Yakah, 2012). The findings in this study indicate that cocoa farmers in the surveyed areas have

Table 6. Relationship between the knowledge of pollination and the cocoa production system.

Cocoa production system ^a		B	Std. Error	Wald	df	Sig.	Exp(B)
Conventional farming	Intercept	12.093	3.450	12.284	1	0.000	
	Knowledge of pollination	-3.877	2.705	2.054	1	0.152	0.021
	Source of knowledge of pollination	-0.045	0.662	0.005	1	0.946	0.956
	Pollination influences yield	-3.006	1.018	8.723	1	0.003	0.049
	Flower pollination and fruit yield	1.397	0.943	2.196	1	0.138	4.044
	Fate of unpollinated flower	1.390	1.292	1.159	1	0.282	4.016
	Farmers can influence pollination	1.660	0.930	3.181	1	0.074	5.257
	How farmers influence pollination	-0.497	0.424	1.377	1	0.241	0.608
	Pollinators are important	-0.858	0.287	8.921	1	0.003	0.424
	Insect pollinators of cocoa	-1.061	0.560	3.592	1	0.058	0.346

a. The reference category is organic farming

extensive knowledge of the roles of shade trees in cocoa systems.

The majority of the farmers reported that they knew mirids 'Akate' as one of the key pests of cocoa. They indicated the period between August to December as the time of severe pest damage by mirids while others stated pest severity occurring between January and April, agreeing with a study by Adu-Acheampong et al. (2014) that peak mirid numbers fluctuated from January through April and from September through October, displaying a bimodal peak pattern. This shows that farmers could identify this key pest, and as such, know when to initiate the first-line management option to curtail further pest damage on their farms. The respondents reported that they could recognize the damage

symptoms from this pest on their farms, and this confirms the study by Awudzi et al. (2016) that most farmers reported mirids as the most significant insect pest on cocoa. In a bid to manage key pests of cocoa via insecticide application, pollination services may be affected on a short-term basis (Forbes & Northfield, 2017; Pesticide Action Network, 2018). Most farmers leave substrates (cocoa leaf litter, cocoa pod/pod husk, banana and plantain pseudostem) to serve as manure on the cocoa farm, and only about 0.5% of the farmers understood their roles as breeding sites for midges. This buttresses the point that cocoa farmers leave cocoa substrates on their farms for fertilization purposes, while a few others merely left them on their farms due to advocacy of their farmers' association to leave substrates

Table 7. Farmer's awareness of the impact of insecticides sprayed in the four cocoa communities.

Variable	Percentage response				Total	Statistical test	
	A (CC1) (n = 50)	B (OC1) (n = 50)	C (OC2) (n = 50)	D (CC2) (n = 50)		χ	p-value
Knowledge of mirids							
Yes	100	94.1	79.1	100	89.9	16.45	0.001*
Period of severe mirid infestation							
August-December	65.6	36.7	33.3	57.6	50.3	22.99	0.010*
January-April	15.6	46.7	57.6	39.4	39.8		
Others	18.8	16.7	9.1	3.0	9.9		
Time of insecticide spray							
January -April	26.5	28.6	45.5	35.3	34.6	10.99	0.276 ^{ns}
May-August	23.5	10.7	9.1	26.5	17.3		
August-December	41.2	53.6	45.5	35.3	43.6		
Others	8.8	7.1	0.0	2.9	4.5		
Impact on beneficial organisms							
Yes	85.7	5.9	4.7	97.1	48.2	109.57	0.00*
No	14.3	94.1	95.3	2.9	51.8		
Impact on pollinators							
Increases their population	8.6	2.9	2.3	2.9	3.0	108.42	0.00*
Decreases their population	71.4	2.9	2.3	94.1	44.7		
Don't know	20.0	94.1	95.3	2.9	52.3		

A: Addo-Nkwanta; B: Aponoapono; C: Kookoo-Ano; D: Obopekonya. OC1: Organic cocoa community 1; OC2: Organic cocoa community 2; CC1: Conventional cocoa community 1; CC2: Conventional cocoa community 2. *: statistically significant at level 5%; ns: statistically non-significant.

Table 8. Relationship between the knowledge of the impact of insecticides sprayed on the environment and the cocoa production system.

Cocoa production system ^a		B	Std. Error	Wald	df	Sig.	Exp(B)
Inorganic farming	Intercept	13.254	4.416	9.009	1	0.003	
	Reasons substrates are left	-1.557	1.338	1.355	1	0.244	0.211
	Impact on beneficial insects	-5.926	1.502	15.574	1	0.000	0.003
	Impact on pollinators	0.273	1.329	.042	1	0.838	1.313

a. The reference category is organic farming

on the farm to increase yield. This contrasts with the study by Frimpong-Anin et al. (2013) that the majority of its respondents did not know the importance of cocoa pod husk to the cocoa farm.

4.2. Knowledge on pollination

According to Groeneveld et al. (2010), despite increased abortion of the fruit due to high intensity of pollination and limited plant assimilate, the yield of cocoa is influenced by the number of pollinated flowers, at least on a short-term basis. This indicates that pollination deficits in plants can be very high and that greater awareness of pollen and resource constraints may be crucial to the success of effective pollinator-friendly management strategies. The results from this study showed that although some farmers were knowledgeable about how they could influence pollination by hand, they did not fully understand the concept of natural pollination of cocoa, and this could be due to the fact that the major pollinators (midges) are very tiny and minute

insects. Farmers who claimed to be aware of pollination had greater knowledge of artificial pollination via hand pollination but little knowledge of the natural pollination of cocoa. This could be attributed to knowledge acquired through the dissemination of information throughout the country by the media and extension agents after the hand pollination programme in the country (Ghana Cocoa Board, 2018). This is in contrast to Frimpong-Anin et al. (2013) where respondents regarded pollination as one of the trees' inherent physiological mechanisms.

There was a positive correlation between farmers' educational level and their knowledge of insect pollinators of cocoa, which affected their perception of pollination and knowledge of insect pollinators. The highest percentage of formally educated farmers directly correlated with the highest percentage of farmers aware of the concept of pollination (at Obopkonya). The level of formal education in all communities was generally high. However, the significant means of accessing information about pollination was via agricultural extension agents in these communities, which confirms a study by Awudzi et al. (2016) that farmers relied on extension agents to access information about farming practices. Although the outcomes of these extension services have been beneficial to the management of cocoa pests and diseases in Ghana (Baah et al., 2009), a study by Baah and Anchirinah (2011) indicated that the cocoa extension programme is in dire need of immediate policy reforms as most farmers are still unaware of natural pollination of cocoa and pollinator-friendly conservation practices.

The majority of the farmers acknowledged and understood basic principles of pollination and believed that pollination is not necessary for fruit yield, agreeing with Frimpong-Anin et al. (2013) that most respondents did not understand the fundamentals of pollination and, as such, do not believe pollination was necessary for fruit yield. Only 4 out of 87 respondents who understood the concept of pollination seemed to recognize midges as insect pollinators of cocoa. This could be due to the fact that midges are

Table 9. Spearman's correlations (r-values) between response variables.

Responses	Age	Gender	Educational level	Years of experience
Frequency of pruning	0.085 ^{ns}	-0.142*	0.118 ^{ns}	-0.034 ^{ns}
Frequency of weeding	0.148*	-0.037 ^{ns}	0.051 ^{ns}	-0.015 ^{ns}
Timing of insecticide application	0.163*	-0.011 ^{ns}	-0.058 ^{ns}	0.058 ^{ns}
Frequency of applying insecticides	0.04 ^{ns}	0.010 ^{ns}	0.102 ^{ns}	-0.160*
Knowledge on pollination	0.060 ^{ns}	-0.074 ^{ns}	0.088 ^{ns}	-0.092 ^{ns}
Knowledge of insect pollinators of Cocoa	0.148*	-0.114 ^{ns}	0.138*	0.101 ^{ns}
Reasons for leaving substrates	0.077 ^{ns}	-0.130 ^{ns}	0.174*	0.069 ^{ns}

*: statistically significant at level 5%; ns: statistically non-significant

quite minute, and their behavioural attributes may have contributed to them not being recognized as cocoa pollinators. *Apis mellifera* (honey bee) and ants were the other insect pollinators identified by respondents. Most farmers acknowledged extension officers as the source of their knowledge on pollination, thus confirming the work of Awudzi et al. (2016) that peasant farmers utilized extension officers more as a medium for acquiring knowledge.

4.3. Knowledge of the impact of insecticides sprayed on the environment

Although majority of the farmers were aware of one of the key insect pests of cocoa, mirids, farmer attitudes towards the pest varied significantly across communities because the management systems were different amongst the communities surveyed. Communities which practised conventional cocoa farming had most farmers resorting to the use of synthetic insecticides such as imidacloprid, bifenthrin and thiamethoxam, while a pyrethrin-containing bio-insecticide was used to manage these pests in organic cocoa-growing communities even though the application of this insecticide was less frequent compared to the conventional cocoa-growing communities. This agrees with findings by Ayenor et al. (2004) and Boadu (2014) that the use of chemical pesticides is the farmers' key technique in combating pests. Majority of the farmers did not follow COCOBOD's approved insecticide application frequency because they used insecticides to manage insect pests when the pests' impacts were severe. This confirms findings by Denkyirah et al. (2016) that cocoa farmers in the former Brong Ahafo region did not adopt the pesticide application frequency approved by COCOBOD because the spray regime does not seem to effectively manage these pests during the periods they severely affect production. The timing of insecticide application was not significantly different among the communities because farmers were aware of the time of severity of the key insect pest aided by their extension agents and farmers' association, which drives the start of the application. This contrasts with the findings by Awudzi et al. (2016), where most respondents did not have access to insecticide type, frequency and timing information.

Most of the respondents stated that the pesticides applied did not affect beneficial organisms. However, some of the respondents knew of the impact of

insecticides on beneficial organisms, and this aligns with studies by Okoffo et al. (2016) and Nkansah and Somuah (2014) that farmers were knowledgeable about the detrimental effect of pesticides on the environment. Farmers were aware of the effect of pesticides on the environment as advocated by their farmers' association, and from the information from their extension agents. Farmers' groups play significant roles in many agrarian communities by providing access to information, training, agricultural inputs and credits and facilitating farmers' adoption of agroecological innovations (Brako et al., 2021; Iyabano et al., 2021). These means of extension could be leveraged in disseminating information and aligning farmers' perceptions and practices in adopting pollinator-friendly practices in cocoa production Figure 1.

5. Conclusion

Farmers' knowledge and practices on insecticide usage and pollination varied amongst the communities surveyed, highlighting the vital significance of ensuring farmers have clear knowledge of pest management, which is crucial as they mainly depend on the use of insecticides in the management of insect pests of cocoa. There is the need for swift intervention, vast awareness-building and technical creativity, along with partnerships between researchers and disseminators of scientific knowledge to farmers to enable them to tackle the risk of pollinator decline on cocoa productivity as farmers have little knowledge on the impact of these insecticides on the environment. It is also imperative to educate farmers on the importance of pollinator-friendly management practices as they acknowledge artificial pollination as the only means to augment cocoa pollination. There is a need for partnership between the Ghana Cocoa Board and other public and private stakeholders, including certification groups, to educate farmers and extension agents on the impact of indiscriminate insecticide application on the environment and the usage of selective insecticides and pollinator-friendly conservation measures.

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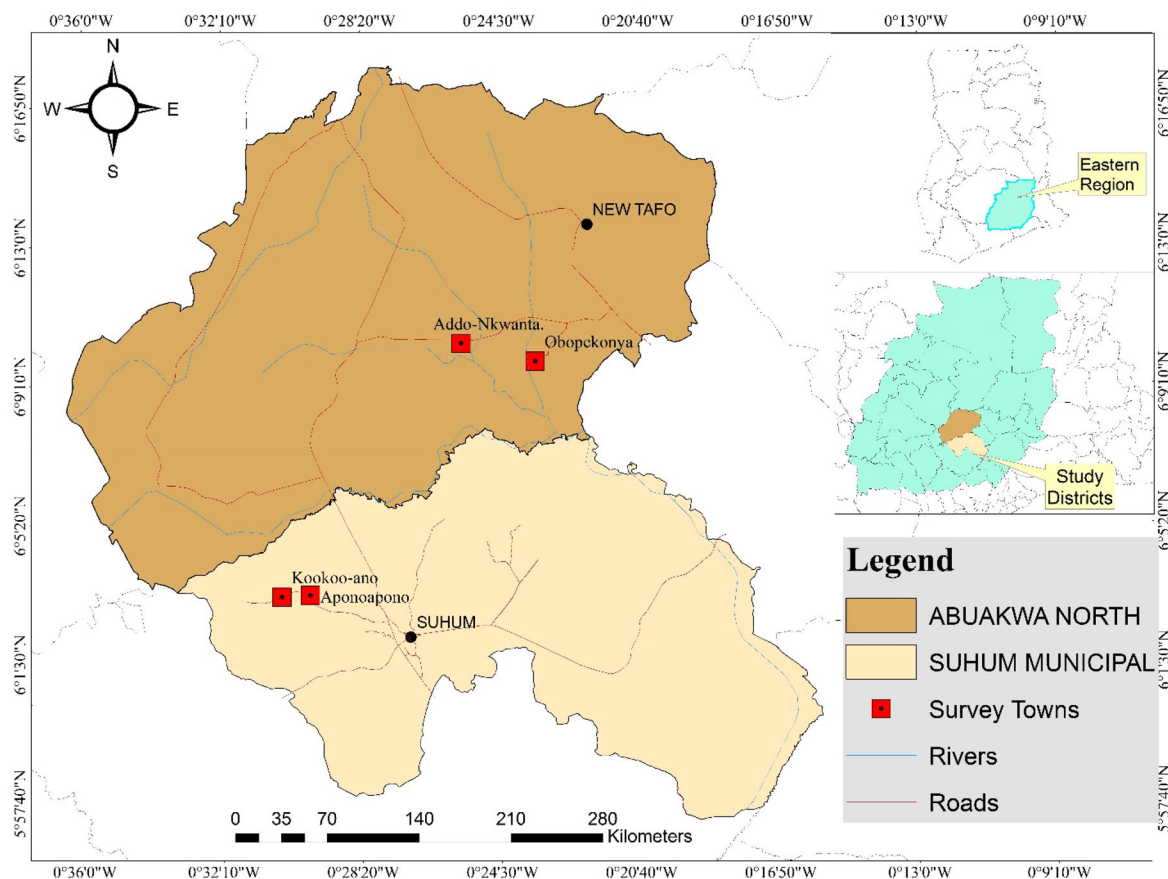


Figure 1. A map showing the study locations in the Eastern region of Ghana.

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Notes on contributors

Blessing C. Umeh, is an MPhil Entomology graduate of the University of Ghana, and currently works at the Nnamdi Azikiwe University in Nigeria. Her research focuses on global change

ecology as regards beneficial insect conservation and management. We live in a world where humans are having profound impacts on the global environment and her research tends to investigate how these factors impact ecological systems and human societies at large.

Silas W. Avicor, PhD is a Research Scientist at the Cocoa Research Institute of Ghana. He is an Entomologist and a Molecular Biologist with interest in Molecular Entomology, Xenobiotic Science, Toxicology and insect pests and disease vectors of medical and agricultural importance.

Dr. Enock Dankyi, PhD is a senior environmental chemist at the University of Ghana. His research focuses on the exposure, fate and effect of pollutants, including pesticides, in the environment. His work aims to design strategies for reducing the impact of these chemicals on the environment and biodiversity, including humans.

Rosina Kyerematen, PhD is an Associate Professor of Entomology at the Department of Animal Biology and Conservation Science and the Dean of Student Affairs at the University of Ghana. She is a Systematic Entomologist with interest in Insect Systematics and Taxonomy, Aquatic Entomology, Climate Change, Biodiversity and Ecosystem Services.

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