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Cocoa farmers' awareness of pollination and its implication for pollinator-friendly practices

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ABSTRACT

Scarcity of information on farmers' knowledge on pollination and pollinator conservation prompted a survey of farmers' and agricultural extension officers' awareness of pollination and possible impact of farm practices on cocoa pollination. The survey was carried out in three cocoa growing areas in Ghana, using structured questionnaires. Cocoa farmers were unaware of cocoa pollinators and their ecology and thus have not intentionally developed pollinator management practices, although some of their practices were pollinator-friendly. All the extension officers had good understanding of pollination but its importance was downplayed, and they did not know the identity of cocoa pollinators. Eighty-eight percent of the farmers were unaware of the concept of pollination in general, and 100% did not know the identity of cocoa pollinators. Both farmers and extension officers were also oblivious of the importance of cocoa pod husks as the predominant breeding substrates for cocoa-pollinating midges. It is concluded that cocoa farmers' knowledge of pollination is very poor, and educating farmers on pollination as an agricultural input will not only benefit cocoa but other pollinator-dependent crop cultivated by cocoa farmers.

KEYWORDS

Pollinator;
Ceratopogonid midge;
Cocoa pod husk;
Farmers;
Flowers;
Breeding substrate;
Insecticide.

INTRODUCTION

Pollination is a key process in seed and fruit formation, making it a critical determinant in food production and on farmers' incomes. It also forms vital link between wild and agro ecosystems, as wild pollinators service cultivated crops[2,9]. Services of pollinators, particularly insects, are under-appreciated because insects which are studied are usually determined by 'tangible' economic considerations, and public and private funding agencies usually tend to support control of pests rather than encouragement of pollinators[7,31]. There are however increasing reports of declining pollinator populations in many agricultural systems, culminating in a reduction in fruit set as well as deformed fruits and seeds. Examples have been reported in coffee[22], cashew, watermelon and apple[28].

Cocoa is a cash crop of great value to many West African small-holder farmers. The crop requires cross pollination and this is effected mainly by midges belonging to Ceratopogonidae and Cecidomyiidae[20]. Inadequate midge population therefore results in insufficient pollination, and this insufficiency has been reported as major cause of low fruit set in some cocoa plantations[6,15,36]. Notably, studies on natural pollination of cocoa in West Africa have not been encouraged[4], although the region accounts for 70% of world's total cocoa production[3]. Intense studies on natural pollination of cocoa in West Africa were undertaken between 1950s and 1970s[18-21,30]. Research thereafter has been only sporadic[4--6,32] although growing conditions and production concerns for cocoa have change over the period. An instance is the mass application of insecticides in all cocoa farms in Ghana under the Cocoa Diseases and Pest Control (CODAPEC) programme. Available documented studies on cocoa pollination showed: 1) the gap in research providing practical guidance to farmers, due to weak agricultural extension services, and 2) that farmers' knowledge and the impact of farm practices on pollination have not been documented, possibly due to low rate of adoption of innovations by farmers. A major reason attributed to this is the popular top-down approach where farmers' opinions are mostly disregarded[3]. Taking inventory of farmer practices and their influence on cocoa pollinators may therefore form a baseline for further scientific studies and improved adoption rates by indigenous farmers.

One way the FAO is helping developing countries popularize pollinator-friendly practices is through the "conservation and management of pollinators for sustainable agriculture, through an ecosystem approach" project, under Global Pollinator Project. The project has adopted the Study, Training, Evaluate and Promote (STEP) approach, which aims at equipping and disseminating information on pollinator-friendly practices. Ghana is one of the beneficiary countries and cocoa is one of the focal crops. A baseline survey for a successful implementation of the project was carried out and this paper therefore highlights the cocoa farmers' knowledge on pollination and pollinator conservation practices, in attempt to answer the following questions:

1 Is the cocoa farmer aware of the concept of pollination?
2 Do they undertake pollinator conservation as part of their management practices?
3 What are the implications of their knowledge towards pollinator-friendly practices in the cocoa ecosystem?

Supplementary information on pollination from extension officers and how this information is disseminated among farmers are also discussed. To conclude the study, data gathered are synthesized to map out pollinator-friendly implementation strategy among cocoa farmers in Ghana.

MATERIALS AND METHODS

Study areas

The survey was carried out in three major cocoa growing areas in Ghana, viz Kubease-Wuraponso (Ejisu-Juabeng District, Ashanti Region), Abrafo-Ebekawopa (Twifo Hemang Lower Denkyira District, Central Region) and Edwenease (Mpohor Wassa East District, Western Region). Each community comprises a village and a number of hamlets.

Sampling

Farmers, and cocoa extension officers were sampled between February 2007 and January 2010. A pre-tested structured questionnaire was used to elicit information on farmers' knowledge on pollination in general and pollinators of cocoa in particular. Information regarding the identity, breeding sites and alternative forage resources of cocoa pollinators, farmers' cultural practices and insecticide application regimes were gathered. A total of 97 out of 100 targeted cocoa farmers were interviewed with the aid of the structured questionnaire which was interpreted in the local language (*Akan*), on one-on-one basis. Prior to administering the questionnaire, the local chief or renowned cocoa farmers were contacted for the names of all cocoa farmers in the communities. In all, 112 out of 171 names (this was to make way for selected but unavailable farmers at the time of the interview) were randomly selected for the interview. The total number of interviewees per community depended on the number of names provided and the proportions were 19.6%, 43.3% and 37.1% for Kubease-Wuraponso, Abrafo-Ebekawopa, and Edwenease respectively. Nevertheless, all the females (total of 9) were included due to their low numbers in all the communities. Thirty-two of the farms of interviewees were visited, and 18 of them were selected for monitoring over the study period, to assess the validity of some of their assertions during the interview.

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Informal group discussions were also held with 15 extension officers to identify the content of their curriculum for cocoa extension services. Their understanding of pollination and how they facilitate pollinator-friendly practices among the farmers were also assessed.

Processing the information

Percentages of responses were computed. Chi-square tests of homogeneity of ratios of farmer responses from the three locations, and independence of knowledge in pollination from other pollination variables were also carried out using Minitab version 13.3. Some of the parameters investigated could not be validly analyzed statistically because of low numbers (x<5) of responses.

RESULTS

The farmers were predominantly males (90.7%) while sex ratio among extension officers was even. All the farmer respondents were over 30 years old, with 68.0% being illiterate while 32.0% were primary/junior school graduates. There were significant differences in the literacy level among the three communities with

TABLE 1 : Farmers' awareness of pollination in three cocoa growing regions in Ghana

Variable	Percent responses				Homogeneity		Independence#	
	Kubease-Wuraponso (n=19)	Abrafo-Ebekawopa (n=42)	Edwenease (n=36)	Total¥ (n=97)	χ^2	p-value	χ^2	p-value
Sex								
Male	89.5	90.5	91.7	90.7	0.244	0.885ns	na	
Educational level								
Illiterate	52.6	66.7	77.8	68.0	13.993	0.001*	13.993	0.001*
Basic	47.4	33.3	22.2	32.0				
Knowledge in pollination								
Yes	21.1	14.3	5.6	12.4	8.285	0.016*	na	
Flowers can yield fruit without pollination								
Yes	78.9	83.3	83.3	82.5	5.960	0.202 ns	4.141	0.126 ns
No	10.5	4.8	2.8	5.1				
Don't know	10.5	11.9	13.9	12.4				
Fate of unpollinated flowers								
Drop	100.0	97.6	97.2	97.9	na		na	
Unaffected	0.0	2.4	2.8	2.1				
Pollination influences yield								
Yes	21.1	14.3	5.6	12.4	31.930	0.000*	1.421	0.491 ns
No	42.1	23.8	19.4	25.8				
Don't know	36.8	61.9	75.0	61.9				
Pollinators are important								
Yes	10.5	2.4	0.0	3.1	na		6.164	0.046*
No	84.2	92.9	97.2	92.8				
Don't know	5.2	4.8	2.8	4.1				
Humans can influence pollination								
Yes	26.3	11.9	8.3	13.4	13.762	0.001*	16.372	0.000*
How humans influence pollination								
Hand pollination	10.5	2.4	0.0	3.1	na		na	
Spray insecticide	89.5	97.6	100.0	96.9				
Knows breeding/nesting sites of cocoa pollinators								
No	100.0	100.0	100.0	100.0	na		Na	

¥Pooled responses from all three locations; # Chi test of knowledge in pollination and the other variables; * = significant at 5% level; ns = not significant at 5% level; na = statistically invalid due to low number (x<5) of responses

Edwenease recording the highest level of illiterates (d.f.=1, $p<0.05$) (TABLE 1). There was a link (d.f=1, $p<0.05$) between farmer educational level and knowledge in pollination.

Cocoa farmers

The majority of farmers (87.6%) were ignorant of the general scientific concept of pollination. They perceived pollination to be one of the intrinsic physiological mechanisms of trees. Only 12.4% knew and understands the fundamentals of pollination and 82.5% believed that pollination is not needed for fruit set (TABLE 1). Knowledge in pollination did not influence farmers responses as to whether flowers can yield fruit without pollination (d.f.=2, $p>0.05$). However, 5 (5.1% of sampled farmers) of those farmers who understand pollination cited self-pollination as means by which plants bear fruits without the aid of pollinating agents. The 12.4% (12) farmers who understand pollination claimed to have acquired their knowledge through agricultural extension officers, school/literature and personal observation (TABLE 2).

TABLE 2 : Responses on further pollination issues by farmers who have some knowledge on pollination

Variable	Number of responses¥ (n=12)
Source of knowledge on pollination	
a. Through extension officers	5
b. School/literature	3
c. Personal observation	4
Reasons why pollinators are important	
Increase yield	3
Effect pollination	3
No fruit without them	2
Not important due to self-pollination	4
Cocoa pollinators identified by farmers	
Honey bees (*Apis mellifera*)	2
Sweat bees *Hypotrigona* sp.)	3
Midges (*Forcipomyia* sp.)	0
Don't know	7
Farmers opinion on mode of promoting cocoa pollinators	
Habitat provision	7
Provision of forage resources	5
Protection from fires etc.	1
Protection but don't know how	6
Culturing in the farm	1
No protection	2
Don't know	2

¥Pooled responses from all the three locations.

The few farmers who understood pollination also believed that pollination plays critical role in yield of their cocoa and thus a major yield determinant (TABLES 1 and 2). These farmers therefore considered pollinators as very important compared to the assertion that pollinators were not important by farmers who were ignorant of pollination.

The general responses that unpollinated flowers drop off the tree (97.9%) were based on two assumptions depending on knowledge on pollination. Farmers familiar with pollination attributed it to failure of fertilization. Those ignorant of pollination likened it to leaf flush, referring particularly to the high flower drop observed in February to April. To the latter group, flowers formed in February/March are designed to drop to pave way for production of flowers intended to set fruit after April.

Only 5 out of 12 farmers knowledgeable in pollination claimed to know the identity of cocoa pollinators. The two types of insect pollinators mentioned were the honey bee *Apis mellifera* and the sweat bee *Hypotrigona* sp. (TABLE 2). The farmers were unaware of the role of midges and therefore follows that they did not know cocoa pod husks are potential breeding substrates for cocoa pollinating midges (TABLE 3). Nevertheless, respondents claimed that cocoa trees near cocoa pod husk dumps, created after breaking pod to remove seeds, give higher yield. This area was also alleged to be high spot incidence for black pod disease but respondents were ignorant of the fact that blackpod infested cocoa pod husks amongst the heap could be the source of the infestation.

TABLE 3 : Mportance of cocoa pod husks to cocoa farm

Percent responses¥	Variable (n=97)
Importance of cocoa pod husks to cocoa farm	
Midges breeding site	0
Habour vector of black pod disease	0
Fertilizer	34
Don't know	63

The possibility of humans aiding pollination through hand pollination or pollinator management or other perceived method was asserted by few farmers (13.4%). Farmers responses on the role of humans in pollination was, however, significantly influenced (d.f.=1, $p<0.05$) by their understanding of pollination (TABLE 1). Irrespective of knowledge on pollination, however, there was a general belief among the farmers (96.9%) that fruit set could be aided by spraying insecticides. They believe that beside killing pests, the insecticide is absorbed by the tree and therefore capable of influencing physiological processes involving fruit set hence improve fruit set.

Herbicide application seems to be gaining popularity among the farmers although slashing is still the preferred choice of weed control. Although 46.4% of farmers have once or twice applied herbicide in their cocoa farms within the last 5 years, its use was not consistent, due to the perception that herbicides can adversely affect cocoa trees after prolong application.

Agricultural extension officers

The extension officers' curriculum for cocoa was designed to offer farmers the capacity to use good agricultural practices in cocoa production. This could broadly be categorized into the following thematic areas:

1. Planting and soil: Facilitating the supply of good planting materials and making sure that the right planting procedures are followed.
2. Pests and diseases: These form major components of their programme. Particular attention is devoted to the management of mirid pests which are said to cause up to 35% losses annually. Diseases of particular importance include black pod and cocoa swollen shoot virus disease.
3. Weed and shade: This section ensures that farmers who intend to use herbicides use only recommended ones. Shade management, general pruning and effective removal of parasitic mistletoes are also promoted.
4. Post-harvest: Officers encouraging farmers to employ long-standing norms of fermenting and drying cocoa beans, which is key to the maintenance of the reputation for premium quality enjoyed by Ghana in the international market.

It is evident that pollination as an input in cocoa production has not been prioritized in the extension services curriculum. All the extension officers, however, exhibited good understanding of general pollination but not the elaborate processes involved in cocoa pollination. They did not also know the identity of cocoa pollinators and therefore breeding requirements, although some claim to have come across 'midges' in their studies. The general belief was that the cocoa flower is pollinated by bees, based on their resemblance to other bee-pollinated flowers.

DISCUSSION

Farmers' responses show their low educational status, to some extent, influenced their understanding of pollination. This is evident from responses. The highest proportion of literates corresponded to highest proportion having knowledge in pollination (at Kubease) whereas the reverse was true at Edwenease. Literacy level was nevertheless very low in all the communities, hence the obvious mode of acquisition of information on pollination was through agricultural extension services and personal field observations. The inadequacy of agricultural extension provision in the cocoa sector in Ghana[3] is corroborated in the results, where information sourced from this area was insignificant. However, agricultural extension should have been the prime mode of transfer of knowledge on good crop management practices, including pollination, especially where greater proportion is either illiterates or semi-literates.

In addition to the low level of extension services, pollination as invaluable agricultural input is not prioritized in the extension curricula. This undoubtedly has resulted from common notion that pollination service is free, and has therefore not been economically quantified in many agrosystems, including cocoa[8]. This assertion is supported by the fact that annual yield losses attributed to mirid pests and black pod diseases in Ghana has been estimated to be about 35% and 40-100% respectively[1,3,27]. Pest, disease and soil management as well as developing high early-yielding cocoa varieties seem to have preoccupied researchers, policy makers and training institutions thereby pushing issues relating to pollination to obscurity. These are prominently featured in the programmes such as CODAPEC and cocoa high technology. Importantly, all cocoa varieties being promoted are self-incompatible and require insect pollinators, and thus pollination in the cocoa ecosystem should not be ignored.

Beside information passed on by researchers through extension services, indigenous farmers usually acquire their farm knowledge through what they personally observe in the field, or such observation passed on to them by other experienced farmers[17]. Morphological and behavioural attributes of midges might possibly explain why farmers were unable to recognize the presence and activities of midges by "personal observation". Midges are tiny (about 2 – 3mm), cryptic, and actively pollinate at dusk, night and morning[20,34]. They commonly breed in rotting cocoa pod husks and leaf litter, which are common in cocoa farms, yet farmers failed to recognize them. This is because midge larvae and pupae which are commonly seen in rotting cocoa pod husk and water collected in depressions on tree trunks resemble mosquitoes, and were considered as such by the farmers. On the other hand, the inability of extension officers who have been extensively trained on cocoa to name midges as cocoa pollinators, let alone identify them, is a major knowledge gap. The knowledge gap needs to be closed The reintroduction of cocoa extension officers may help reduce their ratio to farmers in the near future, but training on pollination must be emphasized to help promote pollinator-friendly practices, A team of researchers should also be assigned the role of reviving pollination research and also monitoring compatibility of promoting pollination services along with other management practices such as pests and diseases.

A. mellifera is a common generalist pollinator in cocoa farms but is unlikely to be an effective pollinator of cocoa. The size, structure and fragility of cocoa flowers cannot accommodate relatively large pollinators like *A. mellifera*, while smaller bees like *Lasioglossum* sp. (Hymenoptera: Halictidae)[21] and *Hypotrigona* sp. (*Liotrigona parvula* Darchen)[11,12] visit cocoa flowers and may be able to effect pollination. Frimpong *et al*. (2009) did not record any *A. mellifera* on cocoa flowers when farms of some of the farmers' who were surveyed in this study were sampled. Cocoa farmers privy to information on pollination, reiterated that their knowledge was based on other crops other than cocoa. These reasons might have contributed to the misidentification of *A. mellifera* as a cocoa pollinator.

The cocoa tree flowers throughout the year and about 700 to >18,000 flowers are produced per annum, depending on the variety and health of the cocoa tree[25]. Whilst peak flowering occurs in February-April and June, and ebbs in August-December, the midge population peaks in July-November and ebbs in January-March[11,12]. The asynchrony between peak flowering of cocoa and midge population results in low fruit set, causing high flower drop and not flower flushing as purported by the farmers. This ignorance could be a good reference point to arouse interest of farmers on the role of pollinators in crop yield. It must however be emphasized that improving pollination services will not drastically increase flower setting and subsequently yield to the extent that 'flower carpet' seen at peak flowering will cease, but at least there will be improvement in setting and yield[26]. This is because the cocoa tree produces excessive flowers and under heavy hand pollination, increased matured pods are produced but correspondingly high number of pods wilts before reaching maturity; mainly due to intrinsic physiological constraints and environmental factors such as drought and soil fertility[26].

Hand pollination has been practiced in cocoa seed gardens in Ghana for decades but the ordinary cocoa farmer appears to be uninformed of the act. Though training farmers to hand pollinate cocoa will put further burden on their already strained time and resources, it is prudent to let them know the influence of pollination on yield, in addition to agronomic inputs like fertilizer and pesticides. A better yet cheap alternative to hand pollination is conserving the population and activities of the natural pollinators, of which the major ones are the midges.

The cocoa farmers' belief that increased insecticide spraying corresponds to increased fruit set and subsequently yield underlines the extension of spraying period from the conventional August-December regime through February-July, after the mass spraying of farms through the CODAPEC programme. Spraying insecticides between February and July tends to severely reduce the already precarious midge population resulting from the effect of drought between December and March[12]. Although the mirid population may surge in February[24], insecticides must be applied only when that does happen.

The few farmers conversant with pollination, though ignorant of the identity of cocoa pollinators, appreciated the critical relationship between pollinators and crop yield. A good knowledge of cocoa pollinators relative to the cocoa ecosystem would have given them a better knowledge base to develop pollinator-friendly practices. For instance, they thought pollinators should be conserved but did not know how this could be done.

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Meanwhile, both the informed and uninformed passively undertook some pollinator-friendly practice like keeping cocoa pod husk dumps in their farms. While the cause was unknown to the farmers, they had observed that cocoa trees near pod husk dumps usually give relatively higher yield coupled with increased black pod incidence. These observations stem from the recognition that rotting cocoa pod husks are major breeding substrates of midges[5] and therefore heaped husks created unlimited breeding resources thereby building dense midge population within that vicinity. This dense pollinator population accounts for the increased fruit set and yield of cocoa trees near the dumps. Infested pod husks also harbour *Phytophthora* sp., the causative pathogen of black pod disease[1] and this explains the high incidence of the disease purported by the farmers. To realize the benefit of the pod husk dumps in increasing yield, infested pod husk must be separated for destruction during pod breaking.

Farmers' attribute of non-preference for herbicide usage in their cocoa farms is another good practice which could benefit pollinators. Herbicides do not directly affect pollinators but might kill important weeds which may serve as alternative forage resources[16]. On the other hand slashing maintains weed diversity thereby sustaining the diversity of insects including pollinators. Other cultural practices may provide breeding substrates, alternative forage resources or refugia for the pollinators. These practices include leaving shade trees in the farm and weeds at the farm boundaries, as well as intercropping cocoa with other crops. For example, banana or plantain intercropped with cocoa increases populations of pollinating midges and pod-set of cocoa throughout the season[13].

It must be noted that farmers do not cultivate only cocoa but also other pollinator-dependent crops as well. The need to create the awareness of pollinator conservation among cocoa farmers will therefore benefit not only cocoa but also other pollinator-dependent crops.

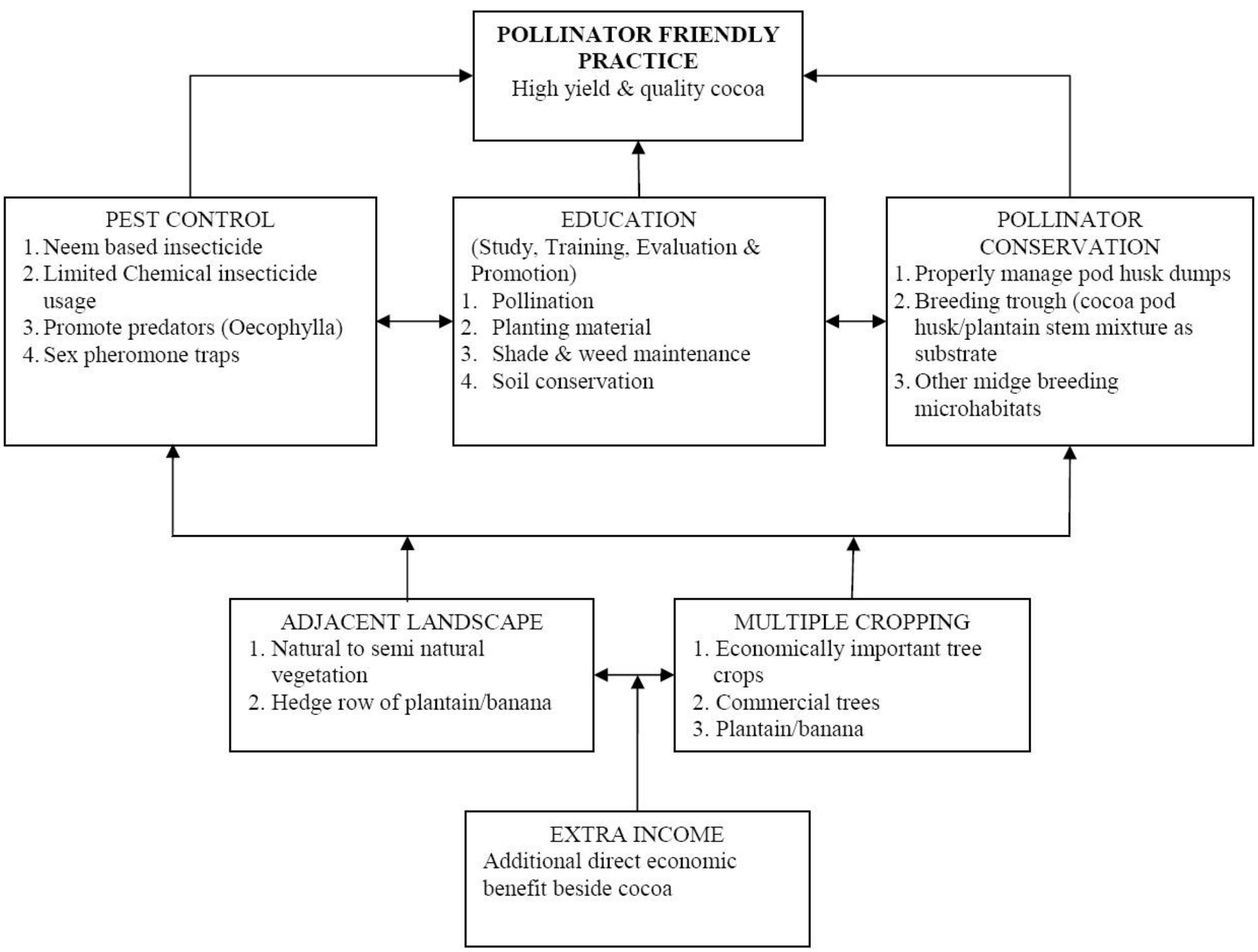

Figure 1: Cocoa pollinator-friendly model for small holder cocoa farming in Ghana.

Promoting pollinator-friendly practices through STEP approach

The survey shows lack of understanding of pollination on the part of farmers as well as a lack of practical knowledge among extension officers. This means farmers needs to be educated on the basics of pollination and its relevance to pollination, whilst extension officers needs to be trained on functional pollination through practical experience. The Study, Training, Evaluation and Promotion (STEP) system employs a single training platform for both parties. The STEP protocol is modeled after the Farmer Field School (FFS) and has been widely adopted by FAOs pollinator conservation project[33].

The project will run for 5 years and it is designed to revolve around selected renowned cocoa farmers at the site. This is because the survey showed that lateral information flow (farmer-farmer) was common, and therefore equipping influential farmers will ensure the dissemination of the right information. For instance, farmers enquire from colleague farmers whose trees are doing well and may go to the extent of collecting planting seeds from them, contrary to the recommendation that all seeds should be sourced from cocoa seed production unit. This is because current varieties are hybrid and therefore yields and vigour of the off-springs are low. The focal farmers are being given additional training through frequent interactions with the researchers and pollinator-management workshops. The model below (Figure 1) has been developed through the survey and field experiments.

CONCLUSION

The survey revealed two major ideas of pollination among the cocoa farmers. The first is the scientific concept of pollination in which pollen is transferred to stigma of flowers. The second was more common among the farmers: the belief that flowers naturally set fruits (cherrel) without any external aid. Although extension officers are aware of pollination, they and the farmers were unaware of the identity and ecology of cocoa pollinators. With the identity and ecology of pollinators unknown, it is natural that farmers do not deliberately undertake cocoa pollinator conservation practices. There should be conscientious effort to educate and promote pollination processes and pollinator conservation as important crop production input among extension officers and farmers.

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