UNIVERSITY OF CAPE COAST

THE ROLE OF INSECT FLOWER VISITORS IN COWPEA (*VIGNA UNGUICULATA*) AGRO-ECOSYSTEM IN THREE DISTRICTS IN THE CENTRAL REGION OF GHANA

BY

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JULY, 2008

DECLARATION

CANDIDATE'S DECLARATION

I hereby declare that this thesis is the result of my own original work and that no part of it has been presented for another degree in this university or elsewhere.

.... Date: 14-09-2011

WISDOM HARRISON KOFI HORDZI

SUPERVISORS' DECLARATION

We hereby declare that the preparation and presentation of the thesis were supervised in accordance with the guidelines on supervision of thesis laid down by the University of Cape Coast.

.... Date: 14-09-2011

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ABSTRACT

Despite its numerous beneficial uses, there is controversy among research scientists about the main type of pollination of cowpea. Therefore, what role do cowpea insect flower visitors play in cowpea agro-ecosystems? In order to answer this question and others this study was undertaken to assess the role of insect flower visitors in cowpea agro-ecosystems in three districts in Central Region of Ghana. The findings would help pest control practitioners to devise appropriate measures to control cowpea pests without destroying useful insects and pollinators. Proportional random sampling was used to select 110 cowpea farmers and 50 Agricultural Extension Officers from the three districts. Questionnaire was the main instrument used. Field experiments were also conducted to find out the role of insect flower visitors in cowpea agro-ecosystems.

Majority of farmers (98.1%) and Extension Officers (88.6%) indicated that pollinators transfer pollen grains from anthers to stigmas of flowers. However, 1.9% of farmers and 11.4% of Extension Officers stated that pollinators destroy flowers. Flowers visited by *Xylocopa calens* and *Megachile* sp. developed more pods and seeds than control flowers. Also, leaves of progenies of flowers visited by *Megachile* sp. were not as photosynthetically efficient as the leaves of progenies of control flowers. Progenies of flowers visited by *Megachile* sp had significantly higher phosphorus and protein content than progenies of control flowers. One implication of the findings is that progenies of flowers visited by *Megachile* may develop reduced leaf area. However, further research will confirm this.

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LIST OF ACRONYMS

API	African Pollinator Initiative
CONTROL FLOWER	Flowers not exposed to any organism (or self-pollinated flowers)
DSID	Direction de Statistique Apricole, de l'Informatique et de la Documentation
FAO	Food and Agriculture Organization
IFAP	International Federation of Agricultural Products
SAFGRAD	Semi-Arid Food Grain Research And Development
SARI	Savannah Agricultural Research Institute
SRID	Statistical Research and Information Directorate

CHAPTER ONE

INTRODUCTION

Background

This study is mainly concerned with investigating the role of insect flower visitors in cowpea agro-ecosystems in three districts in the Central Region of Ghana. The background to this study comprises four components. These are: exposition on cowpea and its importance, pollination and pollination services in cowpea agro-ecosystem, pesticide application and its effects on pollinators and pollinator services, and issues about what cowpea farmers and Agricultural Extension Officers know about pollination in general and cowpea pollination specifically as well as effects of pesticides on beneficial insects and probable pollinators in cowpea agro-ecosystems.

Farms and cowpea

Agriculture plays a very important role in the economy of Ghana. It is estimated that about seventy per cent of the working population of Ghana is in the field of agriculture (Awuku *et al.,* 1991). Going round the country one can see different types of crops under cultivation. The sizes of the various farms of the crops under cultivation generally depend on the economic importance of the crop or the capabilities of the farmers. Since Ghana largely depends on cocoa for foreign exchange, cocoa farms are generally big. Other important crops in the country are oil palm, coffee, citrus, cassava, rice, millet and sorghum. Some of these crops can also be grown on large, average or small scale depending on the motive and capability of the farmer. Some other crops are generally grown on subsistence level, though they form part of the regular food chain of the country. One of such crops is cowpea.

Generally, farms can be considered as agricultural ecosystems (Internet-http://www.novelguide.com/a/discover/biol02/biol_02_00230.html). An ecosystem is the basic functional unit of nature made up of living organisms and their non-living environment (Ramalingam, 1993). Butani (2006) defined an ecosystem as interacting system of living organisms in an area and their physical environments. Taylor *et al.* (1997) defined it as biotic and abiotic components of an area. Therefore, an agro-ecosystem is an ecological socio-economic system, comprising domesticated plants and / or animals and the people that husband them, intended for the purpose of producing food, fibre or other agricultural products (Conway, Internet).

Cowpea (*Vigna unguiculata*) [L]) Walp) originated in Africa, where it has become an integral part of traditional cropping systems, particularly in the semiarid West African savanna (Imrie, 1998). There are three recognized sub-specific groups of cultivated cowpeas, namely, *unguiculata* (cowpea), *cylindrica* (cat-jana) and *sequipedalis* (yard-long, asparagus bean) (Onwueme and Sinha, 1991). Cowpeas vary in growth habit from erect or semi-erect types with short (less than 100days) growth duration grown mostly for grain, to longer (more than 120 days) duration semi-erect to trailing plants grown primarily for forage (Imrie, 1998). Cowpeas are grown on a wide range of soils but show a preference for sandy soils which are less restrictive of root growth (Imrie, 1998). This adaptation to lighter soil is coupled with tolerance for drought through reduced leaf growth, reduced water loss through stomates, and leaf movement to reduce light and heat load when stressed. On the contrary, cowpea has poor tolerance of waterlogging (Imrie, 1998).

Of the crop's estimated world total area of 10 million ha, Africa alone accounts for over 7.5 million ha of which about 70% lies in West and Central Africa (Singh *et al*., 1996; cited by Singh and Tarawali (internet) - http://www.ilri.cgiar.org/Infoserv /Webpub/Fulldocs/Cropresidues/chap%204.htm). Worldwide production exceeds two million tones but only a small proportion enters international trade. The major producing areas are Africa, Asia and the Americas (Imrie, 1998). The crop is primarily grown in mixtures with cereals, especially maize in the moist savanna and sorghum and millet in the dry savanna.

The young tender leaves, pods and peas are used as vegetables, whilst snacks and main meal dishes are prepared from the dried grain. The plant tolerates drought and fixes nitrogen, thus improving soil fertility. The ability of cowpea plants to tolerate drought and poor soils makes it an important crop in savanna regions where these constraints restrict other crops. After the cowpea pods have been harvested, the rest of the plant can be used as animal feed. Thus, farmers in the dry savanna use cowpea haulms as a nutritious fodder for their livestock. The plant's ability to fix atmospheric nitrogen helps maintain soil fertility, while its tolerance to drought extends its adaptation to drier areas (Singh and Tarawali, Internet- http://www.ilri.cgiar. org /Infoserv/Webpub/ Fulldocs/ Cropresidues/chap%204.htm).

Cowpea is grown mainly for its grain, which contains between 22 and 32% protein on a dry weight basis (Fatokun, Internet- htpp://www.iita.org/details/ cowpea-pdf/cowpea-1-5.pdf). Therefore, cowpea grain which is valued for its high nutritive quality and short cooking time serves as a major source of protein in the daily diets of the rural and urban poor. Singh and Allen (1980) and Chalfant and Young (1988) also reported that cowpea is high in protein, to the extent that the grain contains about 25% protein, making it extremely valuable where many people cannot afford protein foods such as meat and fish. Hence, the grain is one of the cheapest sources of protein in the diets of peoples of West and Central Africa where cowpea is also an important crop (Fatokun, Internet- htpp://www.iita.org/details/ cowpea-pdf/cowpea -1-5.pdf).

The dried grain is consumed after being processed into different food forms while the haulms from dried shelled pods are a good source of quality feed for livestock. As a result, farmers in the dry savanna areas of West and Central Africa derive some income from selling cowpea fodder to livestock owners, particularly during the dry season (Fatokun, Internet-htpp://www.iita.org/ details/cowpea-pdf/ cowpea-1-5.pdf). The predominant grain type traded is the "blackeye pea", a large white seed with a black patch around the helium, although markets exist for seeds with a range of sizes and colours (Imrie, 1998).

In Ghana for that matter the research area cowpea is mainly grown at subsistent levels. It is common to come across maize, rice, millet, sorghum and even cassava mixed with cowpea on the same farm. In Ghana a number of improved cowpea varieties have been recommended to farmers. Some of such recommended varieties are Soronko, Amantin, Asontem, Vallenga (Ghana/CIDA Grain Development Project, 1988; Adu-Dapaah *et al.*, 2005), Asetenapa, Adom, Ayiyi, Bengpla, Boafo and Marfo-tuya (Adu-Dapaah *et al.*, 2005). However, farmers rarely plant these recommended varieties, especially in the research area. In the research area the farmers mostly plant the variety known as blackeye. The reason given by farmers for this was that the variety is easy to cook and swells very much. Farmers do major rainy season sowing between April and June while the minor rainy season's sowing is done between August and October. The farmers process the dry cowpea seeds into many local edible forms. Examples are 'kose', gari and beans, boiled beans and fried ripe plantain, rice and beans popularly known as 'waakye', boiled beans and maize popularly known in Ewe as 'aboda', etc.

The fact cannot be denied that cowpea is of tremendous value to mankind for that matter Ghanaians. No doubt some farmers use it as cover crop mainly because it can fix nitrogen for the soil thereby reducing or eliminating the application of chemical nitrogenous fertilizers that can in the long term be harmful to human health. It is equally clear from literature that every part of cowpea plant is very useful to the extent that the leaves can be eaten, used as fodder or manure on soil surface; and the roots are capable of fixing nitrogen for the soil. Since cowpea seeds can serve as useful source of protein and the plant's ability to tolerate drought makes it a preferred crop for low income as well as savanna and dry regions. Obviously, cowpea is used for variety of meals in Ghana and other West African countries which are of low income status. Therefore, it will be in the interest of people of such low income and dry regions to show more interest in understanding factors that co-exist with the crop in its natural settings that can enhance its productivity. Hence, the current study is just an attempt to understand how insects contribute to cowpea production in the research area.

Pollination and cowpea

A number of interactive relationships exist between plants and animals in the ecosystem. One of such relationships is the interaction between flowers and flower visitors. A flower visitor can be any animal that visits the flowers of a plant (Internet- http://www.geocities. com/insectpollinators/visitors. html? 20073). To attract visitors, plants use various cues such as shape, colour and smell, and they usually provide a food reward (Eardley, 2002). Many flower visitors end up causing pollination whilst others just end up obtaining food from the flowers and others are predators that feed on pollinators (Internet – http://www. geocities. com

/insectpollinators/visitorshtml?20073).

Pollination is the transfer of pollen grains from an anther to a receptive floral stigma (African Pollinators Initiative (API), 2003). Pollination takes place by means of animals (pollinators), wind and water. Pollinators are organisms that transfer pollen grains from the anther to the stigma of the same flower or different flower of the same plant or another plant of closely related species resulting in fertilization. Eardley (2002) considers pollinators as animals that provide pollination services. No animal pollinates flowers deliberately. They visit flowers for food, in the form of nectar, pollen and plant oils. Pollination precedes fertilization and fertilization results directly in the plant producing seeds and fruits (API, 2003).

Seeds are the means by which plants manage to disperse to new sites. They are also means by which plant species can persist in a dormant phase, during times of drought or other stress conditions. Seeds and fruits are also food for many people and animals (API, 2003). Eardley (2002) and Abrol (1997) stated bees, wasps, ants, flies, butterflies, beetles, moths, bats and birds as typical pollinators. However, some plants have unusual pollinators such as rodents (Eardley, 2002) and slugs (Internet-http//www.geocities.com/insectpollinators/visitorshtml?20073).

Mammalian pollinators are mainly man, bats and mice whilst snails and birds can also cause pollination (Abrol, 1997).

Pollination is an essential ecosystem service. Worldwide, it has been realized that pollination is a service nature provides that humans have tended to take for granted (API, 2003). An estimated two-thirds of all flowering plants depend on animals, largely insects for pollination services. For these plants, the pollinator can be as critically important as light and water (API, 2003). Therefore, pollination is a vital link in natural communities, connecting plants and animals in key and essential ways.

Cross-pollination by insects is very key to the survival of many flowering plants. Teale (1957) also observed that insect pollination is an essential link in the ecological global chain. It has been estimated that more than 100,000 species of wild plants depend upon insects for pollination and reproduction (Teale, 1957). The absence of insect pollinators would have a drastic effect on non- cultivated areas, because most of the soil holding and soil enriching plants would disappear. Again, pollination may be needed by many wild species to produce fruits and nuts that are eaten by birds and small mammals. Thus, insect pollination is of utmost importance for continuation and propagation of plants, which maintain environmental quality.

Because insects have become so adept at finding and identifying individual flowering plants, even rare plants may persist so long as pollination occurs (API, 2003). The wealth of types of pollinators, from butterflies to bees to birds and bats and the wealth of varieties within flowering plants have stimulated each others' evolution, leading to a remarkable diversity and often beautiful adaptations between flowers and pollinators (API, 2003).

Conserving pollinators in an ecosystem means preserving the finely tuned links between plants and animals that make it possible for plants to reproduce successfully. In turn, especially in the harsh environments found throughout Africa, plants offer a rich and critically vital resource to animals in the form of pollen, nectar, seed, fruit and foliage (API 2003). Ecosystem services contribute significantly to global employment and economic activity. Hence, changes in ecosystem services influence all components of human well being such as the basic material needs for a good life, health, good social relations, security, and freedom of choice and action. Bees are valuable pollinators of 95 crops in the United States and bee pollinated crops have a farm value of approximately $10 billion. Honeybees contribute large sums of money through sale of honey products (Ellis *et al.*, 1998). Klein *et al.* (2003) and Roubik (2002) observed that fruit set of highland coffee increases with cross-pollination by bees. The value of pollination by honey bees to agriculture has been estimated to exceed the value of hive products by about eight to ten folds. The value of pollination to the sustainability of natural terrestrial ecosystems cannot be estimated because without pollination many ecosystems would change drastically (Ahmad *et al.*, 2006).

Pollinators are extremely important to agriculture and nature conservation (Eardley, 2002). Cross-pollination brings about hybrid effects in plant progeny leading to qualitative and quantitative changes in the economic and biological development of the plants (Abrol, 1997). Some of such quantitative and qualitative changes stated by Abrol (1997) are stimulation of germination of pollen on stigmas of flowers, increase in viability of seeds, embryos and plants; formation of more nutritive and aromatic fruits and increase in the vegetative mass and faster growth of plants. Others are increase in the number and size of seeds and yield of crops, increased nectar production in the nectarines of plants, increased fruit set and reduction in fruit drop, enhanced resistance to diseases, and increased oil content in oil seed crops (Abrol, 1997). The ecosystem service of food production contributes by far the most to economic activity and employment. The degradation of ecosystem services often causes significant harm to human well-being (Millennium Ecosystem Assessment, 2005). However, the information available to assess the consequences of changes in the ecosystem services for human well-being is relatively limited. Pollinators provide useful ecosystem services. Almost all flowering plant species of tropical rainforests are pollinated by animals (Bawa, 1990) and one-third of the human diet in tropical countries is derived from insect pollinated plants (Crane and Walker, 1983).

Therefore, the worldwide decline of pollinators can cause decline in crop yield (Kevan and Philip, 2001).

API (2003) also asserted that pollination is a service that is very key to agriculture. Just as pollination is pivotal to agriculture for quantity, quality and diversity of foods, fibres and medicines, it is also essential for maintaining biological diversity (Ahmad *et al.*, 2006). Insect pollinators are essential for many fruit and vegetable crops and the demand for pollinators grows as the need for agricultural productivity increases. Pollinators have real commercial values, although this is not always appreciated. For example through pollination and high yields of crops, some West African beetles provide about US $150 million-plus per year in Southwest Asia (API, 2003). However, remarkably little is known about pollinators in Africa. Virtually, nothing is known about the effectiveness (API, 2003) and mode of pollination in Africa. For example, the distribution, yearly abundance, population fluctuations and true rarity which need to be thoroughly studied (Ahmad *et al.*, 2006) are non-existent. As a result it is difficult to know whether pollinator species are threatened or naturally rare. A search through the literature provides no or very little information on pollinators and pollination in Africa especially West Africa and particularly Ghana. Literature is so scanty or nonexistent on pollinators of our farm crops to the extent that a crop such as cowpea which is known to exhibit both self and cross-pollination (Purseglove, 1974) is generally considered as self-pollinated by many African research scientists.

Since cross-pollination brings about hybrid effects in plant progeny leading to qualitative and quantitative changes in the economic and biological development of the plants then it is obvious that pollinators are extremely important to agriculture and nature conservation. Therefore, there are a lot of implications for the survival and perpetuation of cowpea varieties if the crop is only self-pollinated. Since cross-pollination can lead to increase in viability of seeds, and Seeds are the means by which plants manage to disperse to new sites it is likely that if cowpea is only self-pollinated, with time seed viability would have been at it's lowest. This would have led to low level of germination and eventual extinction of the crop. Also since cross-pollination brings about enhanced resistance to diseases, self-pollination is a dangerous thing for cowpea because if only self-pollination occurs then the plants would be very susceptible to various diseases and eventual elimination of the plants. Furthermore, since worldwide decline of pollinators can cause decline in crop yield (Kevan and Philip, 2001) if cowpea is only self-pollinated then cultivated cowpeas might be producing below the potential level of production. However, if cross-pollination also takes place in cowpeas it is likely to make up for the negative effects of self-pollination and thereby lead to seeds of high viability and plants with high productivity. Furthermore, since cowpea has not yet gone extinct there is the likelihood that cross-pollination is possible. The researcher's argument and dilemma is rooted by the fact that pollination is pivotal to agriculture for quantity, quality and diversity of foods, fibres and medicines; it is also essential for maintaining biological diversity (Ahmad *et al.*, 2006). However, the researcher's dilemma is confirmed by the fact that despite the usefulness of pollination, a search through literature gives an indication that there is controversy surrounding cowpea pollination. For example, Mackie and Smith (1935), Buchmann and Nabhan (1996) reported cross-pollination. Bubel (1987) also reported self-pollination for cowpea. Meanwhile, Vaz, De Oliveira and Ohashi (1998); and Asiwe (2009) observed that cowpea undergoes both self- and cross-pollination. Apart from the confusion, further search is suggesting that African scientific research findings concerning cowpea pollination that were reported are either scanty or non-existent. This raises the question as to what kind of cowpea pollination takes place in our environment. However, such a question can only be answered through scientific research such as the current study.

Farmers and Agricultural Extension Officers knowledge about pollination and effects of pesticides on beneficial insects in cowpea agro-ecosystems

Cowpea is also known to suffer destruction from some major pests such as flower thrips (*Megalothripis sjostedti* Trybom), pod sucking bugs and beetles. For example, cowpea curculio, *Chalcodermos aeneus* Boheman (Coleoptera: Curculionidae) cause damage to cowpea crop from seedling stage through to harvest and can cause economic damage at all stages of plant growth (Singh and Allen, 1980; Dupree, 1970; Chalfant and Young, 1988; Omongo *et al*., 1997). As a result insecticide applications to control such pests become very common. However, insecticide resistance has become a problem for some classes of insecticides (N'Guessan and Chalfant, 1990). Not only that but also many commonly used pesticides are harmful to beneficial insects and negatively alter ecosystem services such as provided by probable pollinators of cowpea.

Pesticide use is an age old phenomenon. For example, Machipisa (1996) contended that the use of pesticides gained popularity in the 1960s when they improved yields and killed pests. The problem however is that the overall consumption of pesticides has continued. At the same time pests have developed resistance to the chemicals, and now destroy an even larger proportion of crop yields (Machipisa, 1996). Okorley *et al.* (2002) also asserted that the Ghanaian public and government have come to realize that the use of chemical pesticides by vegetable farmers to control pests and diseases in the country is increasing and if agricultural production is to be sustainable and safe to humans and the environment, then intensive farming systems should become less dependent on chemical pesticides. All these submissions suggest that pesticide application in the country may be on the increase. It is also suggestive that citizens have realized that the use of chemical pesticides is not safe for human existence.

It is also important to note that the abundance of bees and other pollinators is drastically reduced by intensive agriculture and urban development (Ellis *et al*., 1998). Richard (1996) observed that the poisoning of honeybees and other beneficial insects by pesticides can be a serious problem. The most serious problems occur when bees collect contaminated pollen or nectar and carry these materials back to the hive. The residues of some of these pesticides can also be found in traces in food that is produced from the crops and thereby causing long term harm to consumers. For example, analysis of pesticide residues on vegetable samples from Accra, Kumasi and Tamale was undertaken by Amoah *et al.* (2006). Their results indicated that Chlopyrifos (Dursban) was detected on 78% of the lettuce, lindane (Gammalin 20) on 31%, endosulfulfan (Thiodan) on 36%, lambdacyhalothrin (Karate) on 11% and dichloro-diphenyl trichloroethane (DDT) on 33%. The results also indicated that most of the recorded residues exceeded the maximum residue limit for consumption. These results have also brought to the fore that some of the food stuffs that are on the Ghanaian market are not safe for human consumption due to the wrong application of chemical pesticides.

Insecticidal dusts and encapsulated insecticides such as Penncap-M are especially dangerous because they adhere to foraging bees and may be collected and stored in the hive with pollen. Such materials can cause serious bee kills within the hive for many months (Richard, 1996). Pesticide misuse has driven beekeepers out of business, but can affect native wild bees even worse, because they have no human to move or protect them(Wikipedia, 2004).The Wikipedia (2004) further observed that bumblebees are hit over and over when pesticide applicators apply insecticides on blooming cotton fields while the bees are foraging. Widespread aerial applications for mosquitoes, med-flies, grasshoppers, gypsy moths and other insects leave no island of safety where wild insect pollinators can reproduce and repopulate. One such programme can knock down pollinator populations for several years (Wikipedia, 2004).

The fact that in the course of controlling cowpea pests farmers apply agro-chemicals indiscriminately raises concern as to what knowledge they posses about cowpea pollination and pollination services. Could it be that they have any indigenous knowledge accumulated over the years from their farming practices concerning cowpea pollination and pollinator services? Meanwhile, Genetic Resources Action International (GRAIN) (1990) postulated that farmers' innovations and their accumulated knowledge have provided the foundations for thousands of years of agricultural development. Such accumulated farmer knowledge leading to sustainable systems of agriculture was based on the indigenous knowledge of the farmers themselves (Resources Action International (GRAIN), 1990)). However, considering the controversy surrounding cowpea pollination among research scholars and the way the cowpea farmers dispense agro-chemicals one cannot help but find out what level of knowledge they have about pollination services on the crop.

Another important fact is that Agricultural Extension Officers are trained Officers who are expected to have more knowledge about pollination and pollinators and to carry such information from research scientists to the farmers and vice versa. On the other hand, Agricultural Extension Officers most often have lower academic qualifications than research scientists. This makes it difficult for them to understand every scientific research report, let alone making it available to farmers. Considering the fact that it will not be out of place to ask that if research scientists who are expected to furnish Extension Officers with scientific knowledge appear to be lacking useful information on pollination and pollinator services in cowpea agro-ecosystems then what do the Extension Officers themselves know about the subject matter. This is apparently not clear. This also calls for scientific studies to unravel the truth surrounding the knowledge of Extension Officers about cowpea pollination. Hence, this project will attempt to find out what cowpea farmers and Agricultural Extension Officers know about pollination and effects of pesticides on such pollinators in cowpea agro-ecosystems.

Statement of the problem

Majority of flowering plants require insects or other animals to mediate pollen transfer. However, different floral visitors can vary widely in their ability to transfer pollen (Mayfield *et al.*, 2001). The flowers of most plants are visited by diverse types of floral visitors (Jordano *et al.*, 2003). However, there seems to be a controversy over the method of pollination of cowpea. Whilst one school of thought considers it to be self-pollinated (Bubel, 1987; Davis *et al.*, 2003; Asiwe, 2009) another school of thought has it that it undergoes cross-pollination (Mackie and Smith, 1935; Buchmann and Nabhan, 1996) whereas yet another school of thought has it that it undergoes both self- and cross-pollination (Vaz *et al.*, 1998; Asiwe 2009). According to Vaz *et al.* (1998) though autogamous, cowpea (*Vigna unguiculata* (L.) Walp) has a cross-pollination rate of 10%. They continued to state that over several years, the mean productivity of cowpea had declined suggesting a decrease in or absence of pollinating insects in the fields (Vaz *et al.*, 1998).

In an attempt to throw more light on the controversy, it has been asserted that the cowpea flowers are often visited by honeybees or bumblebees (Robbins, 1931) and various other insects that forage upon both the nectar and pollen. The pollen is sticky and heavy, indicating that the plant is not wind-pollinated (Mackie 1946; Purseglove, 1974). Meanwhile, Mackie and Smith (1935) thought that bumblebees are the primary pollinators. Buchmann and Nabhan (1996) confirmed this statement by stating that bees pollinate cowpea. The degree of cross-pollination varies considerably in different areas. In California with its dry climate cowpeas are considered almost entirely self-pollinated; in humid areas in the United States and Nigeria considerable cross-pollination occurs (Purseglove, 1974). Thus, it is possible to have both self-pollination and cross-pollination. Whereas most of the cowpea pollination research findings were reported from elsewhere and appear to be very ancient and scanty in terms of depth and coverage it seems African and Ghanaian researchers have completely avoided reporting on cowpea pollination. This may be attributed to the fact that African and for that matter Ghanaian researchers have concluded that cowpea is self-pollinated and hence there was no need venturing into further studies on it. Even, taking it that cowpea undergoes self- and cross-pollination which of the two gives higher yield? This has not been explicitly established. In Ghana, it is very difficult to come across documented scientific literature concerning the type of insects that visit cowpea flowers and what they do on the flowers. Again it is difficult to tell from existing literature the performance of progenies of cowpea seeds obtained from flowers that might have been pollinated by insects. Could it be that such progenies would give higher yield or not? This can also not be easily answered without scientific investigation. Hence, the researcher thought that the foregoing unanswered mind bordering questions or unclear situations about cowpea pollination in our environments should not be left like that.

With a moment's reflection it becomes self-evident that farmers' innovations and their accumulated knowledge have provided the foundations for thousands of years of agricultural development (GRAIN, 1990). Such accumulated farmer knowledge leading to sustainable systems of agriculture was based on the indigenous knowledge of the farmers themselves (GRAIN, 1990). Meanwhile, with the controversy surrounding cowpea pollination among research scholars one cannot however tell what level of knowledge the cowpea farmers who are always cultivating the crop have about pollination services on the crop. Could it be that the farmers have some indigenous knowledge that can be useful to research scientists? It is difficult responding positively to this question because in Ghana it is not uncommon to find farmers indiscriminately applying agrochemicals which can be hurtful to useful agricultural insects including pollinators.

Agricultural Extension Officers are trained Officers who are expected to have more knowledge about pollination and pollinators and to carry such information from research scientists to the farmers and vice versa. However, can it be said that the Extension Officers are more informed than the farmers on issues concerning cowpea pollination? The fact of the matter is that it is not clear what level of knowledge both the farmers and Extension Officers have about cowpea pollination. Meanwhile, it is the conviction of the researcher that scientific understanding of what cowpea farmers and Agricultural Extension Officer know about cowpea pollination and effects of chemicals on the pollinators may help in pollinator conservation processes in cowpea-agro-ecosystems in the research areas and for that matter Ghana. Hence, this research was designed to undertake a scientific study of the knowledge level of cowpea farmers and Agricultural Extension Officers about cowpea flower insect visitors and the effects of pesticide control measures on them as well as study the role of cowpea insect flower visitors on cowpeas on the field.

Justification

Cowpea is the most widely cultivated legume in Ghana (Awuku *et al.*, 1991). It provides protein for human consumption and fodder for livestock (Marconi *et al.*, 1990). Cowpea can leave in the soil 40 to 70kg nitrogen per hectare after a crop harvest (Singh *et al.*, 1995). It is drought tolerant crop very suitable for cultivation in low rainfall areas of the country (Awuku *et al.*, 1991). In Ghana the following are considered as the benefits of growing cowpea: it serves as a source of protein and minerals; it provides regular income for households; it can be cultivated for leaves, pods and grains; it can be fed as haulm to livestock; and it produces high yields in short period of time. Other benefits associated with cowpea cultivation include: requirement of low inputs, fixation of atmospheric nitrogen and leaving some for the next crop, provision of soil cover and thereby controlling weeds and minimizing erosion (Adu-Dapaah *et al.*, 2005). Therefore, though not grown on large scale, it is undeniable fact that cowpea is a very important crop.

Despite the many beneficial uses of cowpea, the commonest type of pollination of the crop is not yet well known especially in the research area. Could it be self-pollination or cross-pollination? Even if the crop is cross-pollinated then which insects are responsible for it? Could it happen that even if cross-pollination caused by insects takes place at all the progenies of the seeds produced would produce higher yield and better morphological features? The answers to these questions are not easily available in the literature, especially the Ghanaian scientific literature. Generally, pollination as a subject on its own has a lot of missing links in Africa. For example, according to Rodger *et al.* (2004) a review of African pollination biology showed that relatively little work has been done on pollination biology in Africa, and a very small proportion of pollination relationships has so far been studied. They went on to say that much of the research which has been done is of an evolutionary nature. Very little work has been conducted at the community level and comparatively little applied work, either to agriculture or conservation, was encountered. Most research has been conducted in South Africa, in particular, from the Cape region, which is the only part of Africa for which a reasonably comprehensive body of work on pollination biology exists (Rodger *et al.*, 2004). The missing links in pollination research in Africa can be considered as very serious with a crop such as cowpea which is thought to be mainly self-pollinated. Hence, research such as this becomes necessary to study the role of cowpea flower insect visitors in cowpea agro-ecosystems in Ghana. Such a study will help to reveal the role of some insects commonly found on the cowpea flowers in the research area concerned.

With the controversy surrounding cowpea pollination among research scholars one cannot however tell what level of knowledge the cowpea farmers who are always cultivating the crop have about pollination services on the crop in the research area. Meanwhile, it is generally known that farmers have accumulated knowledge known as indigenous knowledge which leads to sustainable systems of agriculture (GRAIN, 1990). However, one cannot tell if cowpea farmers in the research area have such indigenous knowledge about pollination and pollinator services in cowpea agro-ecosystems. This is so because it is common to find cowpea farmers and other farmers in Ghana applying agro-chemicals indiscriminately. No doubt, such chemicals can cause harm to useful agricultural insects including pollinators. While lamenting about what knowledge cowpea farmers could have that would promote cowpea pollination, sight cannot be lost of Agricultural Extension Officers. The Agricultural Extension Officers are expected to give advice to the farmers. Therefore, it is presupposed that the Extension Officers should be more knowledgeable than the farmers on issues concerning pollination and pollinator services in cowpea agro-ecosystems. With that they would be able to give the appropriate advice to the farmers on pollination and pollinator services. However, here also it is not clear as to what level of knowledge the Extension Officers themselves have about pollination and pollinator services in cowpea agro-ecosystems in the research area. What makes these matters worse is that majority of Ghanaian scientific research reports are silent on issues such as these. Therefore, it is not out of place to conduct scientific research into what level of knowledge cowpea farmers and Agricultural Extension Officers have concerning the role of cowpea insect flower visitors and the effects of pesticides on them in cowpea agro-ecosystems in the research area. The determination of the knowledge of the farmers and Extension Officers will enable the researcher to come out with findings that can inform stake holders as to the situation on the ground. This would further prompt the relevant agricultural authorities to take steps to help the Extension Officers and farmers to boost the production of cowpea in the coverage areas and Ghana as a whole.

Purpose and objectives

The purpose of this study was to assess the role of insect flower visitors in cowpea (*Vigna unguiculata*) agro-ecosystem in three districts in the Central Region of Ghana. It was also intended to investigate the knowledge of cowpea farmers and Agricultural

Extension Officers about cowpea pollination and the effects of chemical control on the pollinators in cowpea agro-ecosystems. The specific objectives of the project were to:

- find out what cowpea farmers and Agricultural Extension Officers know about the role of cowpea insect flower visitors and effects of pesticides on the insect flower visitors in three districts in the Central Region of Ghana.
- identify cowpea insect flower visitors and to determine those that render pollination services.
- compare the yield of insect-visited flowers and flowers not visited by any organism or control (e.g. fruit set and pod formation, number of seeds per pod, seed length and seed circumference) during the major and minor rainy seasons of the year.
- investigate if seeds produced from flowers visited by insects when sown will produce plants that have earlier initiation of flowers, higher yields, higher nodulation by roots, higher levels of nutrient from seeds and better leaf chlorophyll induction kinetics than seeds produced from flowers not visited by any organism.

Research questions

The project sought to find answers to the following four broad research questions, namely,

- What knowledge do cowpea farmers and Agricultural Extension Officers have about the role of cowpea insect flower visitors and the effects of pesticides on the flower visitors in three districts in the Central Region of Ghana?
- What special role do cowpea insect flower visitors play in the cowpea agro-ecosystem?

- Would progenies of seeds obtained from flowers not visited by any organism (control) and seeds obtained from flowers visited by insects have the same measurement for morphological features or one would exhibit higher yield parameters (number of pods, seed length and seed circumference, and nutrient content)?
- For measurement of morphological features such as mean leaf area, number of pods, mean fruit abortion values, mean number of nodules per plant and mean nutrient content of seeds of progenies, for each one what would be the relationship between the values for the various blocks (sub-plots) on which the progenies were grown?

Hypotheses

Ho_1: There are no differences between the frequencies of occurrence of various insects on parts of the flowers in the experimental farm during major and minor rainy seasons.

Ho_2: There are no differences between the number of pods formed from flowers visited by various insects and the control in the experimental farm during major and minor rainy seasons.

Ho_3: There are no differences in nutrient content of progenies of flowers visited by insects and flowers not visited by any orgnism (control).

Expected benefits of the research

The outcome of this study will reveal the right things that cowpea famers and Extension Officers know about cowpea flower insect visitors as well as the misconceptions that the two parties hold about the subject. It will further reveal what the farmers and Officers know about the effects of pesticides on cowpea flower insect visitors and probable pollinators in the cowpea agro-ecosystems in the research areas of Central Region of Ghana. Such revelations could help agricultural authorities of the country to come out with appropriate educational programmes to make the parties involved aware of the benefits of the flower visitors and probable pollinators and the need to conserve them. This would in turn help the Extension Officers and farmers to take the appropriate measures that would help boost cowpea production.

The research findings will also help us to know the common types of insects that visit the cowpea flowers and what role they play on the flowers. It will further help to have inner insight into the mode of pollination of cowpea, whether self-pollination, cross-pollination or both occur. Furthermore, the outcomes would reveal if insect visited flowers could produce higher yield or not. Also, the research findings would help give an indication as to whether progenies of seeds collected from pods developed from insect visited flowers would produce higher yield and more superior morphological features than progenies of seeds collected from pods developed from flowers not visited by any organism. Such a finding would help seed growers to produce the right type of seeds that can give good yield. The findings of the study would also inform what appropriate conservation methods should be adopted to avoid damage to useful insects on the cowpea farm. Probably, integrated pest management would be recommended to the farmers so that they would not destroy the useful insects including pollinators. When the pollinators are well managed cowpea production may increase. This can help make cowpea easily available to its consumers, vegetarians and the poor segment of society. The information generated will contribute to existing knowledge and provide the basis for further research.

Scope (delimitations)

This study covered only three districts in the Central Region of Ghana, namely Agona, Ewutu-Effutu-Senya and Gomoa districts. The main criterion used was that there are some farmers in the three districts who do cowpea farming. It was also more convenient working in the three districts as it was difficult going to any other possible districts due to lack of funds. Assessment of cowpea farmers and Extension Officers' knowledge about cowpea insect flower visitors and effects of chemical control measures on the insects concentrated on (i) insects that visit the cowpea flowers, (ii) the role of insect flower visitors on the flowers, (iii) knowledge about pollination, and (iv) knowledge about chemical application in cowpea farms and its effects on the insect flower visitors. The survey of cowpea farms was concerned with collecting baseline data on the main types of insects that visit the cowpea flowers. The experimental farm work also concentrated on insects that visit the cowpea flowers, main parts of the flower that the various insects forage on, fruit set, pod development and seeds formed in relation to the various insects and control, as well as seed length and seed circumference. The morphological studies of the offspring of the seeds harvested from control flowers and seeds harvested from flowers visited by insects focused on number of flowers developed, fruit set, pod development, number of seeds per pod, seed length and seed circumference, chlorophyll induction kinetics, nutrient value of seeds and nodulation. The study entirely covered only insect visitors other than any other group of organisms.

Limitations of the study

Some of the specimens were not identified to species level as a result of lack of experts and key for their identification. Also, it was very difficult getting latest relevant research publications concerning cowpea pollination. There was no chlorophyll analysis of the leaves to find out if the leaves of the progenies of flowers visited by *Megachile* sp. have more chlorophyll than leaves of the progenies of the control. No attempt was made to undertake a study in the form of genetic analysis to ascertain the deposition of pollen grains from other cowpea plants on stigmas by the insects. Also, soil nutrient and nitrogen content analysis was not done before sowing and after harvesting the crop to know the changes in the level of the nutrients and nitrogen in the soil before and after planting the crop. However, these limitations do not negate the outcomes of the study, but rather they will be taken care of in further studies on the subject matter.

CHAPTER TWO

LITERATURE REVIEW

Legumes

A legume is defined as a plant with seeds in a pod that splits into two distinct halves (Cosgrove and Undersander, 2003). Clark (2009) observed that legumes are plants with flowers like the sweet pea and produce their seeds in pods. They are in a class of vegetables that includes beans, peas, lentils and peanuts (Cosgrove and Undersander, 2003; Mayo Clinic staff, 2003). Most plant species sown for pastures belong to one of two plant groups; the legumes and the grasses (Clark, 2009). Clark (2009) further stated that compared to grasses that have long slender leaves, legumes have compound leaves with three or more broad, rounded leaflets and most of them have tap roots that are able to obtain water from deeper in the soil than the roots of grasses. They grow as vines or bushes and develop pods that contain edible seeds. These seeds vary in size, shape and color (Mayo Clinic staff, 2003). Legumes are highly valued because they are rich in protein and yield well without being fertilized with nitrogen. This is because legumes are able to form a mutually beneficial relationship with *Rhizobia* bacteria (Clark, 2009). Hence, Cooperative Extension Service College of Agriculture and Home Economics (2003) indicated that nitrogen fixation in legumes depends on the formation of nodules by *Rhizobium*. Without sufficient nodule mass filled with an efficient, nitrogen fixing strain of *Rhizobium*, nitrogen fixation will be inadequate. Inoculation of legume seed assures *Rhizobium* is present in the root. Legumes are among the most versatile and nutritious foods available. They are good sources of protein and can be a healthy substitute for meat, which has more fat and cholesterol (Mayo Clinic staff, 2003).

Since humans have made note of plant function, the legume family has been of interest (VandenBosch and Stacey, 2003). Not only do legumes provide fodder for animals and nutrition-rich seeds for humans, but ancient cultures were aware of the ability of many legumes to improve the soil, as result of symbiotic nitrogen fixation (VandenBosch and Stacey, 2003). Legumes also serve an integral component of forage agriculture throughout the world (Pederson, 2006). Onwueme and Sinha (1991) stated that the protein requirements of man can be fully met with a balanced cereal-legume diet, or with a legume diet supplemented with specific amino acids. Therefore a combination of soybeans and rice, wheat, maize and beans provides adequate well-balanced nutrition. Onwueme and Sinha (1991) went on to state that legumes especially cultivated for their mature seeds for human consumption are called pulses or grain legumes. However, their immature seeds and the young pods and leaves are also eaten as vegetables. The vegetative parts of grain legumes are commonly fed to livestock after their seeds have been harvested. Species which are cultivated only to feed livestock are called fodder or forage legumes, or if they are grown in mixtures with pasture grasses they are called pasture legumes (Onwueme and Sinha, 1991). In the tropics, legumes that are grown to control weeds, restrict soil erosion and to enrich soil nitrogen are known as cover crops. They are often grown to cover the ground in plantations of trees such as rubber and cocoa (Onwueme and Sinha, 1991).

According to Onwueme and Sinha (1991) archaeological evidence shows that legumes were cultivated before 5,000 BC. This suggests that perhaps the oldest cultivated legume dates back to 3,000BC in China. They further provided evidence that legumes were cultivated in Central and South America from four to six thousand years ago. Meanwhile, the most important world wide legume produced today is soybeans. Another major world edible legume is groundnuts (Onwueme and Sinha, 1991). Besides soybeans and groundnuts, lentils (*Lens esculenta*) which originated form South West Asia and serve as an important food source throughout history, continues to be very significant in Asia and to a lesser extent in parts of Europe (Onwueme and Sinha, 1991).

Both *Phaseolus* and *Vigna* belong to the tribe Phaseoleae of the subfamily Papilionoideae and of the family Leguminosae (Onwueme and Sinha, 1991). The genus *Phaseolus* differs from *Vigna* in that its stipules do not have appendages below their point of attachment to the stem. Its pollen grains are also smooth, not with an open reticulation of raised walls and its entire species have coiled keels whereas most *Vigna* species do not (Onwueme and Sinha, 1991). The best known and the most widespread *Phaseolus* species is *P. vulgaris*, the common bean. Similarly, the most common and most widespread *Vigna* species is *V. unguiculata*, the cowpea which is the most important bean grown in Africa (Onwueme and Sinha, 1991).

Origin and varieties of cowpea

Cowpea belongs to the family Fabacae, subfamily Faboideae, genus *Vigna* and species *unguiculata* (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources). One can ask what is the origin of cowpea? Some authorities feel that cowpea originated either in the southern Sahel of north-central Africa or in Ethiopia, and then spread to Asia and the Mediterranean by way of Egypt (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources). Another view is that it originated in India and was introduced into Africa some 2,000 to 3,500 years ago. From West Africa, they made their way to the Caribbean and then to North America with the slave trade (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources).

Generally, cowpea (*Vigna unguiculata* [L.] Walp) is said to have originated in Africa, where it has become an integral part of traditional cropping systems, particularly in the semi-arid West African Savanna regions (Valenzuela and Smith, 2002). Singh and Tarawali (internet- http:/// www. ilri. cgiar.org/Infoserv/Webpub/ Fulldocs/Cropresidues/chap%204.htm) and Davis *et al.* (2003) describe cowpea as an annual legume which is also commonly referred to as southern pea, blackeye pea, crowder pea, lubia, niebe, coupe or frijole. The history of cowpea dates to ancient West African cereal farming, 5 to 6 thousand years ago, where it was closely associated with the cultivation of sorghum and pearl millet (Davis *et al.*, 2003). Wordwide cowpea production has increased dramatically in the last 25 years (Davis *et al.*, 2003). Out of the world's total estimated production area of 10 million ha, Africa alone accounts for over 7.5 million ha of which about 70% lies in West and Central Africa (Singh *et al.*, 1996). Nigeria is currently the world's largest cowpea producer accounting for about 22% of total production, followed by Brazil, which produces around 10% (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources). However, significant production also occurs in the East African countries of Uganda, Mozambique, Tanzania, and to an increasing extent, Ethiopia (Cisse and Hall, Internet- http://www. fao.org/ ag/AGP/AGPC/doc./ publicat/cowpea_Cisse/ Fig11_Cisse).

In the genus *Vigna* there are 170 species (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources). Out of the 170 spp., cowpea (*Vigna unguiculata*), green gram (*Vigna radiata*) and black gram (*Vigna* *mungo*) are the very important grain legumes of the world. Under the species *unguiculata*, there are three cultivated subspecies, namely, *unguiculata* (cowpea), *cylindrica* (cat-jana) and *sequipedalis* (yard-long, asparagus bean). However, one wild subspecies, *dekindtiana* occurs in Africa. It is believed to be the wild ancestor of the cultivars which were domesticated in the Ethiopian region, or in West Africa, or perhaps widely throughout the African Savanna zone more than 4,000 years ago. It is believed that the earliest cultivars in Africa were most probably spreading, photosensitive, short-day types of the subspecies *unguiculata* (Onwueme and Sinha, 1991).

When cowpeas are grown for their dry seeds, they are known as black-eyed peas, black-eyed beans, China peas or marble peas. ARC Centre of Excellence for Integrated Legume Research (Internet-www.cilr.uq.edu.au/resources) also observed that the common names of cowpea are black-eyed pea, black-eyed bean, crowder pea, southern pea, field pea, and China bean. The cultivars grown for their long immature pods are variously known as yard-long beans, asparagus beans, beans, bodi beans or snake beans (Onwueme and Sinha, 1991).

Cowpeas can be erect, semi-erect, prostrate (trailing) or climbing annual herbaceous legumes (Onwueme and Sinha, 1991; Imrie, 1998; Davis *et al*, 2003). Some are short, upright bush types, and others are tall and vine-like (Valenzuela and Smith, 2002). They possess a deep taproot system with numerous spreading lateral roots in the surface soils (Onwueme and Sinha, 1991). According to Valenzuela and Smith (2002) most root growth of cowpea usually occurs within the topsoil layer, but in times of drought cowpea can grow a taproot as long as 8 ft to reach moisture deeper in the soil profile. The cowpea plant continues to blossom and produces seeds for an extended period (Onwueme and Sinha, 1991). The non-viny type tends to be more determinate in blooming habit and some improved cultivars blossom over a short period. In indeterminate cultivars, flowers and ripe pods are found together on the same plant (Onwueme and Sinha, 1991).

The flowers of cowpea are either white or purple. Most cultivars produce medium (20cm) to very long (50cm or more) peduncles. Each peduncle produces 2-4 or more pods. The pods are smooth (Onwueme and Sinha, 1991; Davis *et al.*, 2003), 15-25cm (Onwueme and Sinha, 1991) or 15.24 to 25.40cm (6 to 10 inches) (Davis *et al.*, 2003) or 7.62 – 15.24 cm (Thomas Jefferson Agricultural Institute, Internet http://www.jeffersoninstitute.org/pubs/cowpea.shtml) long, cylindrical and somewhat curved (Davis *et al.*, 2003). Each pod has 8-20 seeds (Onwueme and Sinha, 1991) or 6 to 13 seeds per pod (Thomas Jefferson Agricultural Institute, Internet - http://www.jeffersoninstitute.org/pubs/cowpea. shtml).

Generally, pod and seed sizes are the chief distinguishing characteristics of the three cultivated subspecies. Onwueme and Sinha (1991) gave the following examples:

- Subspecies *unguiculata*; pods 10-30cm long, pendant, seeds 5 – 12 mm long,
- Subspecies *cylindrica*; pods 7.5 – 13cm long, usually erect, seeds 5-6mm long,
- Subspecies *sequipedalis*; pod longer than 30cm, flabby, seeds usually 8-12mm long (Onwueme and Sinha, 1991).

On the other hand Cisse and Hall (Internet – http://www.fao.org/ag/ AGP/AGPC/doc/publicat/cowpea_Cisse/Fig11_Cisse) asserted that the traits that distinguish cowpea from many other crops currently grown in Africa include: (1) substantial adaptation to drought; (2) high potential to biologically fix nitrogen in marginal soils with low organic matter (<0.2%), high sand content (>85%), and a broad range of pH (4.5-9.0); (3) tolerance to high temperatures during the vegetative stage; (4) tolerance to shade; (5) rapid vegetative growth; and (6) tri-purpose utilization, producing vegetable leaves and pods, dry grain and forage.

The diversity of the variety can be put into two groups, namely, early maturing varieties grown for grain and late maturing varieties grown for fodder. Both types can be planted on the same field (Singh, 1993). In Ghana the recommended cowpea varieties are 'Soronko', 'Amantin', 'Asontem' and 'Valenga' (Ghana/CIDA Grains Development Project, 1988; Awuku *et al*., 1991; Adu-Dapaah *et al*., 2005). Others are 'Asetenapa', 'Adom', 'Ayiyi', 'Bengpla', 'Boafo', 'Apagbala' and 'Marfo-Tuya' (Adu-Dapaah *et al*., 2005). Cowpeas were considered sacred by the Hausa and Yoruba ethnic groups of Nigeria and were used to ward off evil and cure sick children (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr. uq.edu. au/resources).

Cultivation of cowpea

From an agronomic perspective, cowpea is well suited to the agro-climatic-edaphic, technological and socioeconomic situations in Sub-Saharan Africa. (Cisse and Hall, Internet – http://www.fao.org/ag/ AGP/AGPC/doc/ publicat /cowpea_Cisse/Fig11_Cisse). It is a warm-season crop well adapted to many areas of the humid tropics and temperate zones (Davis *et al*., 2003). Valenzuela and Smith (2002) observed that in Hawaii, cowpea grows year-round at elevations ranging from sea level to 1000 feet. At higher elevations (up to 2000 feet), planting should be limited to the warmer spring and summer months. This implies that cowpea tolerates heat and dry conditions, but it is intolerant of frost. Mayet (2008) and ARC Centre of Excellence for Integrated Legume Research (Internet- www.cilr.uq. edu.au/

resources) observed that cowpea is drought tolerant, grows well in poor soils, and because it is also shade tolerant, it is compatible as an inter-crop with maize, millet, sorghum and other cereals.

Because of its high adaptability to drought-prone conditions, relative to other crops, cowpea is the crop of choice in the dry Sahelian and other Savanna zones of western and eastern Africa (Cisse and Hall, Internet- http://www.fao. org/ag/ AGP /AGPC/doc./publicat/cowpea_Cisse/Fig11_Cisse).They cited the example where the Agricultural Research Institute of Senegal (ISRA) recommends cowpea for production in the northern part of the Senegal where soils are sandy, water holding capacity is low, and rainfall is substantially less than in the southern part of the country.

Cowpeas are grown under both irrigated and non-irrigated regimes. The crop responds positively to irrigation but will also produce well under dryland conditions (Davis *et al.*, 2003). Germination is rapid at temperatures above 18^{O}C (65°F); colder temperatures slow germination (Davis *et al.*, 2003). In order to grow a healthy cowpea crop, there is the need to combine improved crop production, protection and post-harvest practices. These include the site selection, land preparation, seed selection and planting. Others are measures against weeds, pests and diseases, cropping systems, harvesting and post-harvesting treatments (Adu-Dapaah *et al.*, 2005).

Site selection and land preparation

Cowpea can be grown in all parts of Ghana (Ghana/CIDA Development Project, 1988). It can be grown on moist soils and requires at least 500mm of rainfall evenly distributed throughout the growing season (Adu-Dapaah *et al.*, 2005).The greatest production occurs in the savanna areas (Guinea, Sudan and Coastal savannas) and the margins of the semi-deciduous forests (forest-savanna transitional zones).

However, heavy rainfall occurring in the forest zones, especially during the major season encourages excessive vegetative growth and higher incidence of diseases. Hence, in the forest zone the cultivation of cowpea is recommended mainly in the minor season (Ghana/CIDA Development Project, 1988; Adu-Dapaah *et al.*, 2005).

Proper site selection is very important (Dugje *et al.*, 2009). Cowpea can be grown on many kinds of soils, namely, sandy soil, puddle wetland rice soils and even on acid soils where soya bean cannot grow (Awuku, *et al.*, 1991). However, there is the need to select a well-drained sandy loam soil for rain-fed cowpea, or inland depressions and along the shores of a lake for dry season cowpea using residual moisture (Dugje *et al.*, 2009). Since cowpea does not tolerate excessively wet conditions or waterlogging it should not be grown on poorly drained soil (Dugje *et al.*, 2009). Rather, well-drained loamy soils are generally preferred. Heavy-textured clay and sandy soils are not suitable and should be avoided (Ghana/CIDA Development Project, 1988; Awuku, *et al.*, 1991; Adu-Dapaah *et al.*, 2005).

According to Adu-Dapaah *et al.* (2005) good land preparation enhances good crop establishment and reduces weed competition. They went on to state that in the forest and transition zones the land can be cleared by slashing with cutlass and *Glyphosate*, a herbicide is applied and planting done directly (conservation tillage). According to Awuku *et al.* (1991) the weeds must be burnt after clearing new land. However, on previously cropped land there is no need to burn the weeds before planting. It is best to plough and harrow the land before planting (Awuku, *et al.*, 1991). On the other hand, Adu-Dapaah *et al.* (2005) observed that the plant debris need not be burnt during conservation tillage. They further explained that conservation tillage conserves moisture, controls weeds, prevents erosion and adds organic matter to the soil. Hence, in the Sudan savanna, conservation tillage should be encouraged.

However, farmers with bullocks and tractors can plough and harrow their fields before planting. Dugje *et al.* (2009) observed that the site should be cleared of shrubs and stubble. Alternatively, the field should be sprayed with Glyphosate (Round-up) at the rate of 4 L/ha (about 2 1/3 milk tins of chemical in a 15-L sprayer or 3 milk tins of chemical in a 20-L knapsack sprayer) to kill emerged weeds. Land can also be prepared manually with the African hand-hoe. The farmer can also plow and harrow the field to provide sufficient tilth for good root growth or he/she can make ridges thereafter if desired. Where the soils are more fragile and prone to erosion, minimum or zero tillage should be adopted (Dugje *et al.*, 2009).

Sowing

Good quality seed is the basis for vigorous cowpea growth, and large yield (Adu-Dapaah *et al.*, 2005). Use of about 12–25 kg/ha of cowpea seeds, depending on the variety, seed size, cropping system, and viability of the seeds is required (Dugje *et al.*, 2009). More seeds are required when erect varieties are used than when prostrate varieties are adopted, because of the closer spacing of the erect variety (Dugje *et al.*, 2009). Also, fewer seeds are required when the cowpea is to be grown in mixture with other crops.

In any case seeds of improved cowpea varieties can be purchased from certified seed growers or registered seed sellers. This is because seeds from these outlets are pure, clean and have better germination percentage and the seedlings grow vigorously (Adu-Dapaah *et al.*, 2005). To be able to obtain high seed quality, the sowing is timed so that the crop flowers close to the end of the rains. This ensures that seeds mature in dry weather while there is stored moisture in the soil (Ghana/CIDA Development Project, 1988; Onwueme and Sinha, 1991). In West Africa, cowpeas are sown at different times depending on the ecological zone. In Nigeria, cowpeas are sown during the first week of July in the Sudan savanna zone; mid-July in the northern Guinea savanna zone; as soon as the late season rain starts in the southern part of the Southern Guinea savanna; and about mid-August in the derived savanna and forest zone (Onwueme and Sinha, 1991). In Ghana, the main rainy season sowing is done between April and July whilst the minor season planting is between August and September (Ghana/CIDA Development Project, 1988; Awuku, *et al*., 1991; Adu-Dapaah *et al*., 2005). Seeds are sown using spacing of 30cm on ridges and 90cm apart. Closer spacing is recommended for higher yields. The spacing of rows is adjusted to the type of cultivars, depending on whether it is erect or spreading type. Row spacing varies from 60 – 100cm and plant spacing from 20 – 40 cm within rows. The erect cultivars are sown at closer spacing than the spreading ones. The recommended seed rate for the spreading type is 10 –15 kg/ha. The seed rate for the erect type is double the spreading type (Onwueme and Sinha, 1991). Planting should be in lines at the recommended spacing. Generally, two seeds per hole about 2.5cm deep (Awuku *et al*., 1991) is recommended. Emergence is epigeal (similar to common bean, and lupin) where the cotyledons emerge from the ground during germination. This type of emergence makes cowpea more susceptible to seedling injury, since the plant does not regenerate buds below the cotyledonary node (Davis *et al*., 2003).

Weed control

Weeds are a serious problem in cowpea production and, if not well managed, can harbour pests and reduce both the yield and the quality of the grain (Dugje *et al*., 2009). Therefore, cowpeas must be protected from weeds in the early growth stage (during the first four weeks after planting), especially when they are sown as sole crop

(Ghana/CIDA Development Project, 1988; Onwueme and Sinha, 1991). The type of weed control measures adopted should be based on the nature of the problem and the resources available to the farmer. Weed control in cowpea could be done during pre-planting and either through manual or chemical means (Dugje *et al.*, 2009). According to Dugje *et al.* (2009) manual weed control is the most common method used by farmers in cowpea production. The farm is mostly weeded twice with the hoe, first 2-3 weeks after planting (Ghana/CIDA Development Project, 1988; Dugje *et al.*, 2009) and secondly at 4–5 weeks after planting to ensure a clean field (Dugje *et al.*, 2009). Poor weed control or delay in weeding causes a drastic reduction in yield (Dugje *et al.*, 2009).

Dugje *et al.* (2009) intimated that where there are troublesome weeds such as sedges and speargrass or when minimum/zero tillage practices are desired the crop can be sprayed with Glyphosate. They went on to state that Glyphosate kills the weeds right from the roots and thus allows the farmer to prepare the field or plant the crop without the fear of the troublesome weeds emerging within the same season. Glyphosate is marketed in different brand names, such as Glycols, Force Up, Round Up, Delsate, Uproot, Sarosate, Touchdown, Clearweed, Kill off, or Bushfire (Dugje *et al.*, 2009).

It is very necessary to keep the weeds down to prevent competition for light, water and nutrients (Awuku, *et al.*, 1991). Weeds can be removed by hoe, by hand or by bullock-drawn implements if sown on flat land. The best recommended control measure is to kill the weeds with selective herbicides. Examples of recommended pre-emergence herbicides are: 1.5kg a.i. metalochlor + 1.0 kg a .i. prometryne per hectare, or 1.5 kg a . i. Metalochlor + 0.8 kg a.i. diuron per hectare (Onwueme and Sinha, 1991).

Water requirement

Cowpea is more tolerant to drought than other crops, which is why it is cultivated in low-rainfall areas. However, early-planted cowpeas may be affected by intermittent drought during the early cropping seasons. Improved varieties with deep rooting systems and drought tolerance will give more stable yields over a wider range of environments. They will also enable cowpea cultivation to be extended further into the arid zone. Several lines with improved drought tolerance have now been identified and efforts are underway to incorporate this trait into the existing improved varieties (Singh, 1987, 1993; Hall *et al.*, 1992; Singh *et al.*, 1995; Terao *et al.*, 1995; Watanabe *et al.*, 1995).

Onwueme and Sinha (1991) observed that in Africa, cowpeas are sown as a rain fed crops. Whenever the rains stop, the crop lives on the stored water in the soil. The amount of water retained depends on the water-holding capacity of the soils. Irrigation is necessary in soils with low-water holding capacity and when rains stop early. This ensures high yields. The plants need to be supplied with water from the beginning of flowering to the time the first pods are well set (Onwueme and Sinha, 1991).

Fertilizer application

According to Onwueme and Sinha (1991) whenever cowpeas are intercropped with cereals or yams, the fertilizer applied to the main crop can meet the fertilizer requirements of the cowpea. In areas of two cropping seasons if cowpeas are sown following a fertilized cereal within the same year, further fertilization is not necessary. However, when cowpeas are sown for the first time in a field, or when the soil is very deficient in nitrogen, a starter dose of nitrogen at 20 kg / ha needs to be applied

(Onwueme and Sinha, 1991). Generally, cowpea does not require a high rate of nitrogen fertilization; its roots have nodules in which soil bacteria called *Rhizobia* help to fix nitrogen from the air (Dugje *et al.*, 2009). Therefore, cowpea plays an important role in providing soil nitrogen to cereal crops (such as maize, millet, and sorghum) when grown in rotation, especially in areas where poor soil fertility is a problem (Dugje *et al.*, 2009).

Bationo and Mokwunye (1991) and Singh (1993) observed that lack of improved seeds, fertilizer and farm chemicals are major bottlenecks in African agriculture and in the West African dry savanna in particular, cowpea and millet yields can be increased several folds just by applying a little fertilizer and two sprays of a suitable insecticide. Generally, cowpeas have a high requirement for phosphorus, especially getting to the end of the growth period. This is because about 80% of the total phosphorus uptake is absorbed in the last 30 days of growth, where most of it is usually translocated to the seeds. Therefore in most parts of tropical Africa, when cowpeas are sown as sole crop but not following a cereal crop in the same year, application of phosphate becomes necessary (Onwueme and Sinha, 1991).

Depending on the phosphorus level in the soil, a dose of 20 – 40kg P_2O_2/ha can be recommended (Onwueme and Sinha, 1991). In areas where soils are poor in nitrogen, there is a need to apply a small quantity of about 15 kg/ha of nitrogen as a starter dose for a good crop (Dugje *et al.*, 2009). If too much nitrogen fertilizer is used, the plant will grow luxuriantly with poor grain yield. Cowpea requires more phosphorus than nitrogen in the form of single super phosphate or SUPA. About 30 kg of P/ha in the form of Supa is recommended for cowpea production to help the crop to nodulate well and fix its own nitrogen from the air (Dugje *et al.*, 2009).

Despite the fact that potassium requirement of cowpeas is very high, the crop has a high ability to draw on the reserves of potassium in the soil (Onwueme and Sinha, 1991). Hence, they do not always respond to potassium fertilization. If fertilizers are to be applied, then they have to be applied in bands below and to the side of the seed row (Onwueme and Sinha, 1991). Awuku *et al.* (1991) recommended 30kg of phosphorus per hectare on plots cultivated for sometime and deficient in phosphorus. They further suggested that phosphate fertilizer should be applied at or before planting. Ghana/CIDA Development Project (1988) also claimed that on well-cropped Guinea savanna where no phosphorus-bearing fertilizer has been applied for several years, application of 50-60 kg P_2O_5/ha can be applied. However, this should be a single element fertilizer rather than 20:20:0 because the nitrogen is not needed. One bag per acre of triple super phosphate is the recommended rate (Ghana/CIDA Development Project, 1988). Adu-Dapaah *et al.* (2005) also observed that phosphates may be applied as super phosphate at the rate of 60 kg P_2O_5 per hectare, and the application should be in a band close to the cowpea seedlings at sowing stage.

Throughout the Sahel, cowpea growth is retarded due to the poor fertility of the region's sandy soils, which are especially low in phosphorus and micronutrients (Bationo and Mokwunye, 1991). Although, cowpea can fix sufficient atmospheric nitrogen to meet most of its requirements, the limited availability of manure and inorganic fertilizers coupled with drought stress and high temperatures frequently result in very low yields (Miller and Fernandez, 1985; Walker and Miller, 1986). Increasing the population of cowpea and groundnut in the cropping system could particularly alleviate this problem by furthering the integration of crop and livestock production, thereby increasing the quantity and quality of manure available. Efforts are being made to develop cowpea varieties with better nitrogen-fixing ability (Miller and Fernandez, 1985; Walker and Miller, 1986).

Diseases

Generally, cowpeas are not all that susceptible to epidemics of disease as other grain legumes. The most important diseases are cowpea wilt (*Fusarium oxysporum*), scab (*Sphaceloma* spp.), brown bloch (*Colletotrichum capsici*) and *Septoria* leaf spot (*Septoria* spp.) (Onwueme and Sinha, 1991). Emechebe and Shoyinka (1985) also asserted that major diseases affecting cowpea are viral diseases, webb blight, *Cercospora*, brown blotch, *Septoria* and scab in the moist savannah and bacterial blight, false smut and ash stem blight in the dry savanna. These diseases not only reduce the plant growth and biomass production but also affect the quality of both grains and fodder (Emechebe and Shoyinka, 1985). For easy control of these diseases, disease-resistant cultivars need to be sown. A mixture of 2.5 kg/ha Dithane M-45 (Manozeb) + 0.6 kg/ha Benlate (benomyl) applied weekly, beginning at 4-5 weeks, checks most diseases (Onwueme and Sinha, 1991). Adu-Dapaah *et al.* (2005) and Awuku *et al.* (1991) also tabulated *Cercospora* leaf spot (*Cercospora canescens*), *Pseudocercospora* leaf spot (*Pseudocercospora cruenta*), Anthracnose (*Colletotrichum lindemutheianum*), *Colletotrichum* brown blotch (*Colletrichum capsici* and *C. truncatum*), bacterial blight, bacterial pastule, Webb blight, cowpea aphid-borne mosaic virus, and root knot nematode and target spot (*Corynespora cassiicola*) as the common diseases that infect cowpea in Ghana.

According to Awuku *et al.* (1991) and Ghana/CIDA Development Project, (1988) the use of recommended varieties, disease-free seeds and treated seeds as well as crop rotation can minimize the incidence of most cowpea diseases especially where seed and crop residues are the sources of infection. Also, most diseases can be prevented from spreading by pulling and burning infected plants. Awuku *et al.* (1991) further recommended dressing of seed beds before planting.

Insect pests

In spite of cowpea's good grain yield potential (1.5-3.0 t/ha), typical yields in Africa and Asia are low (0.24 – 0.30 t/ha), due to poor crop husbandry and high incidence of insect pests that attack the crop from the seedling stage to crop maturity (Singh and Jackai, 1985; Alghali, 1991). Cowpea growers' major problem is how to control insects which damage the crop. This is because all parts of the plant are susceptible to insect pest attacks (Onwueme and Sinha, 1991). Zhu-Salzman and Murdock (2006) also intimated that numerous herbivorous insects attack cowpea, often resulting in severely reduced yields. Cowpeas suffer major yield losses due to insect pests (Ajeigbe and Singh, 2006). Adipala *et al.* (2000) observed that more than 100 field pests of cowpea can be found in most of the crop production agro-ecologies in Africa, but four of these – aphids (*Aphis craccivora* Koch), flower thrips (*Megalurothrips sjostedti* Trybom), the legume pod borer (*Maruca vitrata* Fab. Syn. *Maruca testulalis* Geyer) and pod sucking bugs are commonly encountered and are of economic importance in Uganda. Optimal production in Uganda is severely limited by an array of cowpea insect pests, which infest and damage the crop both in the field and in storage (Nakato, 2009). The cowpea aphid injects a powerful toxin into the plant while feeding and, when populations are large; this can stunt or kill plants. While feeding, this aphid produces a considerable amount of honeydew upon which sooty mold grows. The black sooty mold reduces photosynthesis and may make leaves unpalatable to livestock (The Regents of the University of California, 2009). Farmers of rainfed cowpea/groundnut/millet/sorghum cropping systems in Kano, Nigeria, ranked arthropods as the major production constraint in cowpea in 1991 and 1992 (Bottenberg, 1995). At least 25% of the farmers also reported severe infestations by *Striga gesneroides*, a parasitic weed of cowpea (Bottenberg, 1995).

The major insect pests of economic importance on cowpea are flower thrips (*Megalurothrips sjostedti* (Trybon) (IITA, 1983; Onwueme and Sinha, 1991), flower beetles, pod sucking bugs (Onwueme and Sinha, 1991), legume pod borer (IITA, 1983) *Maruca testulalis* (Geyer), *Anoplocnemis curvipes* (F.), *Clavigralla mentosicellis* (Stal), *Riptortus dentipes*, *Nezara viridula* (L.), *Mirperus jaculus* (Thnb), *Aspavia armigara* (F.) and *Acrosternum acutum* (Dallas) (IITA, 1983). Some of these insects become pests when factors favour their abundance (IITA, 1983).

Among cowpea pests, the bean flower thrips, *Megalurothrips sjostedti* (Trybon) is the most destructive, attacking the reproductive structures of cowpea during plant development (Tamo *et al.*, 1993). Under high infestation, early feeding damage on developing flower buds can cause their shedding, leading to total crop failures (Singh and Taylor, 1978; Singh *et al.*, 1990). Singh and Jackai (1985) also observed that cowpea is attacked by several insect pests such as aphids, thrips. *Maruca* pod borer, pod bugs and bruchid. These pests cause substantial yield losses and reduced quality of grains. *Maruca* pod borer is not important in areas with less than 300 mm annual rainfall, but it is very damaging in areas with more than 500 mm where it may cause up to 100% yield losses.

Karungi *et al.* (2000) studying pest management in cowpea used regression analysis to quantify yield variations in cowpea due to major insect pests, i.e., aphids (*Aphis craccivora* Koch), thrips (*Megarulothrips sjostedti* Trybom), Maruca pod borer (*Maruca vitrata* Fabricius) and a complex of pod-sucking bugs. They found out that variability in pest infestation was created by growing *Ebelat* (an erect cowpea cultivar) in two locations over three seasons and under different insecticide spray schedules. Stepwise regression for individual locations and seasons' data indicated that most of the variation in cowpea grain yields was caused by thrips. They estimated that to the total variation in cowpea grain yields, on average, the major pests contribute 51–69% in Pallisa and 24–48% in Kumi. Thrips alone contribute 35–41% and 13–19% at these two sites, respectively (Karungi *et al.*, 2000).

Cowpea is parasitized by *Striga gesneioides* (Wild) verke and *Alectra vogelli* (Berth), which cause considerable yield reduction. *A. vogelli* is more prevalent in the moist savanna, whereas *Striga* is more widespread in the Sahelian zone where soils are sandy and infertile (Singh and Emechebe, 1991). Several different species of *S. gesnerioides* have been observed in West Africa causing different levels of parasitization in different varieties (Lane *et al.*, 1995).

Adu-Dapaah *et al.* (2005) observed that insect pests constitute the single most important constraint to cowpea production in Ghana. A severe attack by any one of the important pests can cause total crop loss (Ghana/CIDA Development Project, 1988; Awuku, *et al.*, 1991; Adu-Dapaah *et al.*, 2005). The stated pre-flowering cowpea insect pests in Ghana are leaf hoppers (*Empoasca* sp), grasshoppers, aphids (*Aphis craccivora*), and foliage flower beetles (*Ootheca mutabilis*, *Cerotoma* spp.), (Ghana/CIDA Development Project, 1988; Awuku, *et al.*, 1991; Adu-Dapaah *et al.*, 2005). Those insect pests commonly found at flowering times are flower thrips (*Megalurothrips sjostedti*) and legume pod borers (e.g. *Maruca vitrata*). At post-flowering stage, legume pod borer, cowpea seed moth (e.g. *Cydia ptychora*) and pod sucking bugs (e.g. *Clavigralla* spp.) are the commonest pests (Ghana/CIDA Development Project, 1988; and Adu-Dapaah *et al.*, 2005). Cowpea weevils or storage beetles (e.g. *Callosobruchus maculatus* or Bruchids) are cowpea storage pests (Ghana/CIDA Development Project, 1988 and Adu-Dapaah *et al.*, 2005).

Pest control

Efficient control of cowpea insect pests can increase grain yield five times or more (Ghana/CIDA Development Project, 1988). Cowpea pest control can involve the use of synthetic chemicals, organic chemicals and integrated pest management practices which combine the use of synthetic chemicals and other pest control measures. According to Nakato (2009), in the absence of cowpea host plant resistance, insecticide application is a suitable alternative, as currently there is no single variety of cowpea with resistance to all insect pests. Insecticides provide rapid and effective control against important insect pests and the broad spectrum of action of many of them makes it possible to use one or a combination of insecticides to control a complex of insect pests attacking the cowpea crop (Nakato, 2009). Except pod-sucking bugs, Pyrethoids (Cypermethrin and deltamethrin) give good control of most pests (Onwueme and Sinha, 1991). To keep pod-sucking bugs under control, compounds such as dimethoate are effective. This additional treatment also prevents aphid attack, which can sometimes be severe late in the season (Onwueme and Sinha, 1991). Previous studies have shown that continuous use of chemicals in the control of field insect pests is environmentally unfriendly and detrimental to human health (Nakato, 2009). This therefore necessitated the need for better alternatives that are affordable to farmers as well as environmentally friendly with no health implications and Diatomaceous earth (DE) provided the best and available alternative. Diatomaceous earth is an inert substance that abrades the chitinous layer of insects, resulting into dehydration and death (Nakato, 2009).

Verifying the effects of diatomaceous earth (DE) on cowpea field pests in Uganda, Nakato (2009) observed that when DE was applied as a wettable powder, it was observed that at dosage rate of 20 g/m^2 aphid and thrip populations were significantly (P<0.05) reduced, and at 40 g/m^2 pod bug populations were reduced. As a dust, DE of 40 g/m^2 was very effective in reducing aphid and pod bug populations. The effectiveness of DE dust and wettable powder at 40 and 20 g/m^2 respectively was compared against tobacco extract and fenitrothion. Fenitrothion was very effective in reducing insect pest populations in all seasons. DE as a wettable powder was equally effective in reducing aphid populations (Nakato, 2009).

Application of insecticides can control pests and increase yields, but most farmers cannot afford them (Jackai and Daoust, 1986). When unprotected by insecticide application, the cowpea tends to be more vegetative because the flowers and pods are damaged by pests during translocation of carbohydrates from the leaves to pods such that grain yields decrease and fodder increases (Singh and Tarawali, Internet- http://www.cgiar.org/InfoServ/ Webpub/Fulldocs/Cropresidues /chap%204.htm). According to Ajeigbe and Singh (2006) since cowpeas suffer major yield losses due to insect pests, insect resistant cowpea varieties are being developed to minimize insecticide use in integrated pest management. International Institute of Tropical Agriculture (IITA) is also collaborating with other organizations in breeding cowpea varieties for multiple disease and pest resistance. Sources of resistance to major viruses, *Cercospora*, brown blotch, bacterial blight, *Septoria* and scab have been identified and are being used in breeding programmes (Singh *et al.*, 1987; Abadassi *et al.*, 1987; Singh, 1993). In addition, lines with good resistance to aphid and bruchid and moderate resistance to thrips have been selected and these are being used in breeding programmes (Singh *et al.*, 1985; Bata *et al.*, 1987; Singh and Singh, 1990;

Singh, 1993). Good progress has also been made in breeding for resistance to *Striga. gesnerioides* and *Alectra vogelli* (Singh and Emechebe, 1990, 1991; Aggarwal, 1991; Singh, 1993; Atokple *et al.,* 1995; Berner *et al.,* 1995). Efforts are being made to identify sources of resistance to maruca pod borer and pod bugs which are a major problem in moist savannas and more humid regions.

One major way of controlling insect pests is the use of integrated pest management processes. Experiments during the cropping seasons of 2002–2004 at Kano, Nigeria, evaluated four cowpea varieties and five combinations of time and frequency of insecticide treatments (Ajeigbe and Singh, 2006). Ajeigbe and Singh (2006) went on to say that one-spray at flowering stage was better than 1-spray at podding stage. There was no significant difference between no-spray and 1-spray at podding stage. The improved varieties produced significantly higher grain yields than the local variety especially with no or only one spray at podding stage indicating that the improved varieties have some level of field resistance to insect pests (Ajeigbe and Singh, 2006). Combined analysis of the 3-year results indicated maximum gross income for the 3-spray treatment and minimum from no-spray as expected. The improved early maturing varieties, IT93K-452-1 and IT97K-499-4 performed equally well with 2-sprays and 1-spray at flowering, indicating that these varieties do not require more than two sprays. Thus, using a combination of improved early maturing cowpea varieties and time of application, the need for insecticide sprays can be greatly minimized in cowpea production (Ajeigbe and Singh, 2006).

Adipala *et al.* (2000) allerged that the diverse cowpea pest complex dictates that a single control strategy is unlikely to produce satisfactory control. Earlier field studies done in eastern and northern parts of Uganda demonstrated that close spacing (20-30 cm) effectively reduces aphid infestation (early season pest) but seems to promote thrips, legume pod borers and pod bug infestation (Adipala *et al.*, 2000). Late season pests are more effectively controlled by the use of foliar sprays, the type of pesticide depending on the pest profile. Intercropping also offers remedial control, but the crop combination must consider the pest profile, cowpea/sorghum intercrop being effective against aphids and thrips, and cowpea/greengram against legume pod borers and pod sucking bugs. Selected combinations of agronomic, chemical and cultural control measures (Integrated Pest Management), especially when combined with early planting, offer better management options than the use of sole treatments. The success of these packages is highly dependent on the degree and level of farmer involvement and to what extent they are tailored to meet his/her production goals (Adipala *et al.*, 2000).

Harvesting

Onwueme and Sinha (1991) reported that early maturing cultivars mature in about three months whilst late cultivars mature in about five months. Pods ripen unevenly. Therefore, several hand-pickings (4-6) are needed to prevent shattering and damage to pods and seeds by insects. The dry pods should be harvested early when the mature pod begins to dry to avoid weevil attack in the field and to ensure good quality seeds (Ghana/CIDA Development Project, 1988; Awuku *et al.*, 1991 and Adu-Dapaah *et al.*, 2005). The harvested pods should be sun-dried for one week before threshing for storage (Ghana/CIDA Development Project, 1988; Awuku, *et al.*, 1991; Adu-Dapaah *et al.*, 2005). Singh and Tarawali (Internet- http:// www. cgiar.org/InfoServ /Webpub/FulldocsCropresidues/chap%204.htm) reported that in cowpea-millet mixed cropping, the grain cowpea and millet are harvested at the end of August or the beginning of September, while the late cowpea or sorghum, which is also planted late that season, is left in the field until the onset of the dry season (October-November). Harvested pods are dried to reduce the moisture content of the seeds to 10% for safe storage. Thoroughly dried pods are easily threshed with thresher or with hand (Onwueme and Sinha, 1991).

Yields and production

Worldwide, an estimated 7.6 million tons of cowpea is produced annually on about 12.8 million ha. About 64% of that area is in Africa, 21% in the Americas and the rest in Europe and Asia. Nigeria is the largest cowpea producer, accounting for about 22% of the total, followed by Brazil, which produces 10% on 1.144 million hectares annually (Pereira *et al.*, 2001). Langyintuo *et al*. (Internet – http://www. ilri.cgiar.org/infoserv/webpub/Fulldocs/cropresidues/Chap%20) observed that while cowpea is grown throughout West and Central Africa, its adaptation to drought makes it especially important for the Sahel. Langyintuo *et al* (http://www.ilri. cgiar.org/ infoserv/webpub/Fulldocs/cropresidues/Chap%20) continued to explain that, overall, three main production zones can be identified, namely, a primary production zone lying between the 300mm and 1000mm annual rainfall zone, a secondary zone between 1,000 mm and 1,400 mm rainfall; and a tertiary zone above 1, 400mm annual rainfall. The relatively high average yields for Cameroon is probably due to the use of monocrop equivalent area in estimations and may be misleading. In Burkina Faso, reported average yields are about 83% less than experimental on-farm trial yields (Semi-Arid Food Grain Research and Development-(SAFGRAD), 1998). Nambou *et al*. (1999) reported 2.0 t/ha in Togo compared with 0.24 t/ha in Ghana, the estimated researcher-managed on-farm yields of 1.8 t/ha is more than double the average farm level yields (Savannah agricultural Research Institute (SARI), 1999). Reasons for the low yields in most countries include use of low yielding traditional varieties, poor soil fertility, unfavourable weather, insect pests and diseases (Sawadogo *et al.*, 1985; Diehl and Sipkins, 1985; Mortimore *et al.*, 1997; Blade *et al.*, 1997).

Between 1990 and 1999, West and Central Africa annually produced 2.6 million tons on 7.5 million ha, or about 59% of the world's harvested area. Nigeria, the largest cowpea producer in the world accounted for about 65% of the region's supply and Niger, the second largest producer in the region and third in the world, 15%. The remaining 20% was produced in Burkina Faso, Mali, Benin, Ghana, Cameroon, Togo, Senegal, Chad, Coted'Ivoire, and Mauritania (in order of relative importance). Production in Burkina Faso was about 12,000 t/year (Langyituo *et al.*, http://www.ilri.cgiar.org/infoserv/webpub/Fulldocs/cropresidues/Chap%20).

Production costs for cowpea vary depending on the technology used (in particular, varieties, fertilizer, tillage and pest management). Examples drawn from Bean/Cowpea CRSP studies and other sources show that labour often accounts for over 70% of the total cost of production. Cowpea production appears generally profitable, but returns vary widely from place to place (Langyintuo *et al.*, http://www.ilri.cgiar.org/infoserv/webpub/Fulldocs/cropresidues/Chap%20). Under the traditional farming systems, cowpea yields vary between 250-1,000 kg/ha of dry grain. By adopting the recommended practices and good management, yields of between 1,500 and 2,000 kg/ha are possible.

Storage

Insect pests can easily damage cowpeas in storage. Therefore, the seeds have to be dried well before storing. The storage containers should be cleaned and treated with pesticides. Fumigation is also a good control measure (Onwueme and Sinha, 1991).

Groundnut oil can be used to preserve small quantities of cowpea from damage by storage insect pests. This is done by adding 5-10ml of the oil to 1 kg of grain (i.e. 1-2 teaspoonful of oil per full margarine tin of grain). Using unconventional means of measure half beer bottle of cooking oil is needed to treat one mini-bag of cowpea (Ghana/CIDA Development Project, 1988).

Cowpea uses and demand

The cultivated cowpea (*Vigna unguiculata* (L.) Walp) is the most important source of plant protein in the human diet in tropical Africa, particularly in the Sahel region (Marconi *et al.*, 1990; Mayet, 2008). Singh *et al.* (1995) also observed that cowpea grain, which is valued for its high nutritive quality and short cooking time, serves as a major source of protein in the daily diets of the rural and urban poor. It is consumed either as cooked leafy vegetable, green pods, green seeds or dry seeds cooked and mixed with maize or sorghum (Saxena and Kidiavai, 1997). According to Singh *et al.* (1995) the tender leaves of cowpea are eaten as spinach-like vegetable, while its immature pods and seeds are also consumed as vegetables. ARC Centre of Excellence for Integrated Legume Research (Internet- www. cilr.uq.edu.au/resources) the green leaves are boiled and eaten like spinach, while in parts of Sudan and Ethiopia the roots are roasted and eaten. One variety, called the 'yard long bean,' has been used in China since prehistoric times and the extremely long pods are picked young and steamed or stir-fried (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr.uq.edu.au/resources). In the southeastern United States, the black-eye is cooked with ham or salt pork and served with rice and greens on New Year's Day. The dish is called 'Hoppin John' and is said to bring good luck in the coming year (ARC Centre of Excellence for Integrated Legume Research, Internet-www.cilr.uq. edu.au /resources).

Farmers in the dry savanna use cowpea haulms as a nutritious fodder for their livestock. The plant's ability to fix atmospheric nitrogen helps to maintain soil fertility while its tolerance to drought extends as adaptation to drier areas considered marginal for most other crops (Singh *et al.*, 1995).

In West and Central Africa, cowpea grains are primarily in demand for human consumption. This grain legume provides high-quality protein for humans and livestock (Zhu-Salzman and Murdock, 2006). It is used in over 50 different dishes in both whole grain and milled forms (Dovlo *et al.,* 1976). Boiled whole grains are sometimes eaten with oil and seasoning, but more common uses of whole grains are mixtures of cowpea and cereals (e.g. rice and beans) and as an ingredient in soups or stews. Scorched seeds are sometimes used as a coffee substitute (ARC Centre of Excellence for Integrated Legume Research, Internet- www.cilr. uq.edu. au/resources). The important grain characteristics required for these uses are absence of weevils, a sweet taste, high swelling capacity, and quick cooking to save fuel. The most common use of milled cowpea grains in West Africa are fried cowpea balls called ''akara", "kosai", "akla", "accara", and steamed cowpea cakes called "moin-moin", :"Ole-le" , or "tubani" (Dovlo *et al.,* 1976). For these cases Dovlo *et al.* (1976) noted that the cowpea should be easily dehulled and fast grinding as well as having high foaming capacity and short soaking time. According to Nti *et al.* (2005) cowpea is the second most important legume in Ghana after groundnut. They went on to say that cowpea has a protein content of 19-24% and it is a source of quality protein for many people especially in areas where access to animal protein is limiting. Apart from the well known whole cowpea dishes such as rice and beans, gari and beans and bean stew, cowpeas are traditionally processed into flour and used in the preparation of fried or boiled cowpea paste products (Nti *et al.*, 2005).

Valenzuela and Smith (2002) indicated that cowpea is useful as a rotational cover crop to help meet a cash crop's nitrogen needs, to control erosion, and to improve soil properties. Used as a cover crop, cowpea also suppresses weeds and can encourage populations of beneficial insects to defend cash crops from insect pests (Valenzuela and Smith 2002). They further indicated that cowpea grows quickly and will shade and smother weeds, or it may out-compete them for soil moisture and nutrients. Cowpea grown to maturity can be used as a feed (grazed or harvested for fodder), or its pods can be harvested and eaten as a vegetable. The beans are nutritious and provide complementary proteins to cereals (Valenzuela and Smith 2002).

Demand for industrial processing is negligible and largely limited to the use of small quantities of cowpea in Senegal and Ghana for crackers, composite flower and baby foods produced (Langyintuo *et al.*, Internert- http://www.ilri. cgiar.org /infoserv /webpub/Fulldocs/cropresidues/Chap%20).

Per capita consumption for Ghana (Statistical Research and Information Directorate (SRID), 1999), Togo (Direction de statistique Agricole de I'Informatique et de la Documentation (DSID), 1999) and Benin (Servicede la Statisque, 1999) were the same (9 kg/capita/year). Coulibaly (1999) reported 1.5 kg/capita/year for Mali, while Sawadogo and Kazianga (1999) estimated 20% higher for Burkina Faso than Mali. Nigeria produces three times more cowpea than demanded domestically and Mali six times more (Langyintuo *et al.,* Internet-http://www.ilri.cgiar. org/infoserv /webpub/Fulldocs/cropresidues/Chap%20).There is a big market for the sale of cowpea grain and fodder in West Africa. In Nigeria, farmers who cut and store cowpea fodder for sale at the peak of the dry season have been found to increase their annual income by 25% (Dugje *et al*., 2009).

Pollination

Insects and other animals visit flowers to obtain food, usually in the form of pollen or nectar (Memmott, 1999). This can be considered as an aspect of mutually beneficial relationships because the plants obtain in return the services of the pollinators in carrying pollen from one flower to another (Proctor *et al*., 1996) cited by Memmott (1999). For example, the flowers of *Hormathophylla spinosa* (Cruciferae) were visited by at least 70 insect species belonging to five Orders, with Diptera (44% of the total of species) and Hymenoptera (32%) being the most divers Orders represented (Gomez and Zamora, 1999). They went on to say that the number of insect species visiting the flowers of *H. spinosa* ranged from 35 in 1988 to 43 in 1990. The Order represented by most species was Diptera in all years. All floral visitor species made contact with anthers and stigmas during their visits, acting as potential pollinators. Most of the insect species visited *H. spinosa* flowers to collect pollen. Bees and large hoverflies usually gleaned pollen while crawling over the flowering surface (Gomez and Zamora, 1999).

Due to the fact that plants are sessile, they rely on a number of biotic and abiotic pollen vectors (animals, wind, and water) to cause gamete transfer. As a result they use different physiological and morphological mechanisms to regulate mating (Griffin *et al*., 2000). Temporal separation of male and female functions within flowers (intrafloral dichogamy) is one of the most widespread morphological mechanisms and it is found in over 75% of cosexual angiosperm species (Bertin and Newman, 1993) cited by Griffin *et al*. (2000). There are two types of dichogamy; protandry, where anthers dehisce before stigmas become receptive, and protogyny, where receptive stigmas are presented before anther dehiscence (Wyatt, 1983). There is wide variation in the degree to which the two sexual phases are separated among species and sometimes within species (Bertin and Newman, 1993) cited by Griffin *et al.* (2000)

In general, dichogamy is thought to have evolved to reduce interference between pollen imports and exports (Wyatt, 1983). A particularly important form of interference is self-pollination. In species that lack physiological self-incompatibility the contamination of stigmas with self-pollen can lead to self-fertilization, which may reduce fitness if selfed offspring suffer interbreeding depression (Griffin *et al.*, 2000). Dichogamy is widely expected to limit self-fertilization in self-compatible taxa (Cruden, 1988)

Protogyny, in particular is viewed as an 'anti-selfing' mechanism because it provides opportunities for the receipt of outcross pollen before self-pollen is shed, and it is more common in self-compatible than self-incompatible taxa (Bertin, 1993 cited by Griffin *et al.* (2000).

The extent to which dichogamy reduces self-fertilization depends on the:

a) timing of stigma receptivity in relation to anther dehiscence,

b) rate at which outcross pollen is deposited on stigmas during female phase and removed from anthers during male phase (Preston, 1991). In protandrous species, autogamous selfing may occur if viable pollen grains remain in anthers when receptive stigmas are presented (Griffin *et al.*, 2000). Likewise, in protogynous species, autogamous selfing may occur if stigmas are receptive and unfertilized ovules are still available when anthers shed self-pollen (Griffin *et al.*, 2000). Further opportunities for self-pollination arise in protandrous species if stigmas are presented and can receive self-pollen before they become receptive. Consequently, the functioning of dichogamy depends on the rates of pollen deposition and removal, which, in turn, depends on pollinator visitation rates and foraging behavior (Griffin *et al*., 2000).

There are number of other floral characteristics that influence the foraging activities of flower visitors. For example, nectar resource diversity (Potts *et al*., 2004) as well as pollen availability (Stone *et al*., 1999), flower morphology (Neal *et al*., 1998), the combination of sugars present in nectar (Hainsworth and Hamill, 1993), or the presence of other micro-constituents in nectar (Vogel, 1983, cited by Potts *et al*., 2004). Potts *et al*. (2004) studying the relationship between nectar resource diversity and species richness across sites in Mount Carmel National Park Reserve observed that bee species richness has a highly significant positive relationship with nectar resource diversity. Some pollinator guilds, such as bumblebees (Heinrich, 1976) and bats (Nassar *et al*., 1997) depend on flowers that provide relatively high volumes of nectar to support their foraging activities while other guilds, such as hoverflies and small solitary bees, specialize on flowers with very small nectar volumes (Proctor *et al*., 1996, cited by Potts *et al*., 2004) from which large consumers are excluded. There are also guilds such as bats (Proctor *et al*., 1996, cited by Potts *et al*., 2004) and large bees (Willmer, 1988) which require very dilute nectar to maintain water balance during foraging activity. This is a constraint which is particularly marked in hot arid environments (Willmer and Stone, 1997). Daily changes in available nectar affect the identity and abundance of flower feeders (Potts *et al*., 2001), just as seasonal changes (Bosch *et al*., 1997).

Differences in morphology, sensory physiology and foraging behaviour of insects may also result in differences in their effectiveness as pollinators (Schemske and Horvitz, 1984). In generalized pollination systems, the pollinator effectiveness often varies among different insect visitors (Motten *et al*., 1981, cited by Larsson, 2005). Pollinator effectiveness is defined as the single visit contribution by a flower-visitor to the reproductive fitness of a plant. This quality component may be combined with the quantity component, namely, the visitor abundance, and this gives the pollinator importance, which can be given for both male and female plant fitness (Larsson, 2005). Fishbein and Venable (1996) observed that pollination effectiveness can be partitioned into components which include rates of visitation, pollen removal, and pollen deposition. That is not all, but differences in morphology, sensory physiology and foraging behaviour of insects may result in differences in their effectiveness as pollinators (Schemske and Horvitz, 1984). In generalized pollination systems, the pollinator effectiveness often varies among different insect visitors (Motten *et al.*, 1981, cited by Larsson, 2005).

The ability of a pollen grain to successfully fertilize an ovule depends on a number of performance factors, including pollen grain germination rate, growth rate of the pollen tube through the style, and ability of the pollen tube to reach and fertilize an ovule (Stephenson *et al.*, 1992) cited by Kerwin and Smith-Huerta, 2000). According to Kerwin and Smith-Huerta (2000) variation in pollen grain germination and pollen tube growth rate have been well documented. However, the factors that are most important in controlling the speeds of pollen germination and tube growth are not completely understood. Pollen grains must germinate and grow in the presence of maternal stigma and style tissue. Hence, pollen performance may be influenced by characteristics of both the pollen and the maternal pistil through which the pollen tubes must grow (Kerwin and Smith-Huerta, 2000).

Quoting from different authors, Kato and Hiura (1999) stated that in natural plant populations, two proximate limiting factors affecting fruit set, namely, pollen limitation (broad sense) and resource limitations could affect fruit and / or seed set to different degrees in individuals differing in size or physiological conditions, such as light condition. Both quality of pollen (i:e genetically compatible pollen) and quantity of pollen deposited on stigma may be affected by behavioural response of pollinators to floral abundance of individual plant and clump of plants. For plants with self-incompatible mating systems, fruit set is seriously affected by pollen supply from other conspecific individuals. Therefore, in a wild population of self-incompatible entomophilous-pollinated species, variations in local floral density due to heterogeneous spatial distributions of individual plants, may affect the fruit set of individual plants thought to affect pollinator behaviour through attraction effect and hence, deposition of compatible pollen and geitonogamous pollen (Klinkhamer and De Jong, 1993).

Pollen limitation can vary in time and space, and may induce variability in plant fecundity (Gomez, 1993). Among other things background factors such as resource availability can influence reproduction, placing constraints on the role of pollinators (Zimmerman and Aide, 1989). Some studies have shown that there exists inherent pollinator preference for large flowers or large flowering displays (Schemske and Agren, 1995; Connor and Rush, 1996). According to Parker and Haubensak (2002), visitation increases with rewards such as nectar or pollen. They went on by saying that as a result, a large-flowered or highly rewarding species should be a better competitor for pollinators than an otherwise similar, small-flowered species.

Parker and Haubensak (2002), reviewing from Burd (1994) observed that pollinators have long been recognized as an important factor limiting plant reproductive success. Some floral visitors that appear to be pollinators are more properly classified as nectar thieves (Inouye, 1980, cited by Adler and Irwin, 2006). This is because their body shape prevents contact with floral reproductive structures

(Adler and Irwin, 2006). Contrarily, nectar robbers that pierce corollas to obtain nectar can still cause pollination in some plant species (Irwin *et al*, 2001). As a result such floral visitors act more as mutualists than antagonists (Adler and Irwin, 2006).

All pollen-transferring flower-visitors are not only potential mutualists, but also, if the plant is visited by more than one species, potential conditional parasites. Flower-visitors that remove large fractions of pollen and deliver small amounts to receptive stigmas are increasing the plant population's pollen-limitation and thereby lowering the pollinator effectiveness of other flower-visitors present (Larsson, 2005). Each flower visitor taxon possesses a certain level of pollinator effectiveness which is varying with season and between sites, being the result of a constantly changing network interaction of all flower-visitors present. A flower visitor species that is a mutualist in one plant population may become a conditional parasite in another (Larsson, 2005).

According to Food and Agriculture Organization (FAO) Corporate Document Repository (Internet- http://www.fao/docrep/006/y5110e/y5iioe03.htm) pollination is necessary for all seed and fruit production by flowering plants. Transfer of pollen among flowers to allow their reproduction is a very vital mechanism for maintaining life on earth. People harvest the seeds of some crops for food. Examples are oilseed crops, nuts, legumes such as beans and peas, and cereals such as rice and maize. Other crops provide fruits that develop with the seed. Examples are citrus fruits, mangoes and tomatoes. Seed is also needed for the production of the next generation of crops and allows plant-breeding programmes to improve varieties (FAO Corporate Document Repository (Internet- http:// www. fao/docrep/006/y5110e/y5iioe03.htm).

According to Abrol (1997) after thousands of years of evolution and adaptation to local environments, each plant species has specific requirements for transfer of pollen. Many depend on foraging insects to transfer pollen among flowers. Many species of insects visit flowers to seek nectar or pollen. While doing so most of the insects will transfer a few pollen grains and thereby contributing to pollination. Abrol (1997) further contended that insects such as beetles, flies bees, butterflies and moths can cause pollination. The other important pollinators include wasps, flies, ants and thrips (Abrol, 1997). However, honey bees are considered as very efficient pollination agents (FAO Corporate Document Repository (Internet – http:// www.fao/docrep/006 /y5110e/y5iioe03.htm).

Production of hybrid seed crops on commercial scale creates a special need for cross-pollination by insects. A large population of pollination insects is needed to carry pollen from rows of male plants to rows of female plants (FAO Corporate Document Repository (Internet - http://www.fao/docrep/006/y5110e/y5iioe03.htm).

It has been recently shown that the fruit set of highland coffee increases with cross-pollination by bees (Roubik, 2002; Klein *et al.*, 2003). Based on patterns of movement and the presence of dependable populations, Simpson and Neff (1987) considered the major pollinators of *Prosopis velutina* to be medium to large *Melissodes*, *Centris*, *Protoxaena* and *Megachile*. Members of these genera tended to move among flowers more rapidly, and with greater frequency than the smaller *Perdita* and *Colletes* (Simpson and Neff, 1987). Simpson and Neff (1987) also collected 64 species of solitary bees from the flowers of *Prosopis* in one season at a site 48km West of Tucson, Arizona. However, all these authors did not state what exactly the stated flower visitors were doing on the flowers of the various plants.

Simpson *et al.* (1977) also observed that flowers of *Prosopis velutina* (Leguminosae, Mimosasoideae) were visited by a wide variety of insects, including members of the Hymenoptera (bees, wasps, and *Pepsis* spp.), Coleoptera (Bruchidae, Lycidae, Tehebronidae, and Scarabaeidae), Diptera (Syrphidae), and Lepidoptera (Noctuidae, Geometridae, and various butterflies).

According to Gyasi and Enu-Kwasi (2001) small holder farmers in West Africa recognize and value wild bees not only for honey production, but also as principal pollinators particularly of tree crops such as mangoes, citrus and pawpaw. Other pollinators that they value are ants, bats, and small birds. They recognize groves and crevices in tree trunks as important habitats for wild bees (Gyasi and Enu-Kwasi, 2001).

Legumes generally have mixed stories of pollination. Mackie and Smith (1935) and Barrons (1939) observed that the flowers of most cultivars of *Phaseolus vulgaris* (the common bean) are capable of self-pollination although cross-pollination can and does occur to varying degrees, depending upon the cultivar and the pollinator population. According to Rutger and Beckham (1970) *P.vulgaris* is primarily a selfing species. Studying the pollination of beans grown under glass, Mommers (1971) concluded that bees do not influence development of *P. vulgaris*. Diwan and Salvi (1965) observed that beans in India are eagerly visited by *Apis dorsata*, *A. florae*, and *Trigona* spp. However; the flowers are generally ignored by *A. cerana*. Darwin (1858) and Palmer (1967) stated that bees are of benefit to beans, but the kind of bean they referred to is not clear.

Wester and Jorgenson (1951) detected hybrid vigor in all lima bean crosses tested, with production exceeding the best parent in all cases. Wester and Jorgenson (1951 further observed that a high percentage of crossing was needed. Magruder and

Wester (1940), Barrons (1939) Welch and Grimball (1951) and Magruder (1948) asserted that high percentage of crossing naturally occur in lima beans in some areas.

Literature covering cowpea pollination appears to be scanty and outdated. The anthers of cowpea bear sticky and heavy pollen grains (Purseglove, 1984) such that the flowers open early in the morning and close before noon. The extrafloral nectaries at the base of the corolla attract insects (Mackie, 1946). Cowpea is cleistogamous, producing viable pollen and receptive stigma before anthesis. This phenomenon therefore entirely imposes self-pollination on the crop, though out crossing mediated by insects also occurs in nature. Different insect species are known to visit cowpea flowers but not all are responsible for pollen movement associated with outcrossing (Asiwe 2009).

Reporting the findings of a study, Asiwe (2009), observed that only honey bees and bumble bees were responsible for observed level of outcrossing in cowpea. This was because only heavy insects such as honey and bumble bees with powerful vibration from their wings could depress the wings of cowpea flowers and expose their stamens and stigmas for pollination (Asiwe, 2009).

Asiwe's report went on to say that percentage outcrossing in cowpea was low. However, in comparing two patterns of planting, out-crossing was higher in the alternate than the concentric row planting, indicating that more mixtures or off-types would arise when different cowpea varieties are planted in proximate rows of one metre apart. This would increase cost of seed-sorting or removal of off-type in cowpea field. In more serious situation, it would increase the difficulty of identifying true genotypes or hybrids in a segregating population (Asiwe, 2009).

Farmers and extension services

True farming systems- defined as the establishment of an artificial ecosystem to yield a staple food supply (Reed, 1977) first emerged on earth during the Early Neolithic period (Ca. 3500 – 3000BC) in Northern Europe (Cowan and Watson, 1992). From this period onwards, it seems clear that farming has continued to evolve and develop up to the present day, and no doubt will continue to do so (Jennings and Packham, 2001).

Agricultural extension necessarily emerged after the establishment of "true" farming, but exactly when and what brought about its inception is unclear, or at least, is straying into unchartered territory (Jennings and Packham, 2001). The term "extension" and its use in the English language seem to have come into existence in Britain in the 1840s to describe the function of extending university research results to the community (Van den Ban and Hawkins, 1996). Van den Ban and Hawkins (1996) further stated that the title extension was derived from an urge for universities to deliver their findings to society through formal mechanisms. Hence, it was first initiated at Cambridge University in the 1970s, and then replicated in other tertiary institutions. However, there is little doubt that significant forms of extension services existed and had been continually evolving and developing since the 16th century in Europe (Jennings and Packham, 2001)

The potential for broad scale information transfer occurred for European agriculture with the commercialization of printing press (Porter, 2000). This was demonstrated in England where 20,000 published titles emerged during the publications in the 1790s (Porter, 2000). The proliferation of agricultural print media as an early form of agricultural extension contributed greatly to the emerging agricultural landscape up to the late 1700s (Jennings and Packham, 2001). The emergence of extension as an off-farm profession, along with the agricultural research and development sector, has caused the respective agenda for the on-farm domain and the off-farm domain to be separate entities that exhibit varying degrees of mutual independence and exclusivity (Jennings and Packham, 2001). Jennings and Packham (2001) went on to explain that under the Profitable Pastures Project (PPP), both farmers and scientists are considered equal co-researchers, and their interaction is ensured through the participative and dialogical processes of the action research method.

With a moment's reflection it becomes self-evident that farmers ' innovations and their accumulated knowledge has provided the foundations for thousands of years of agricultural development (GRAIN, 1990). Their work has also been crucial for "modern" agriculture, especially in the arena of plant genetic resource use and conservation since it is peasant farmers who have supplied us with most of the genetic material for our staple foods. Sustainable agriculture has become the dominant new theme for development workers. These sustainable systems were based on the indigenous knowledge of the farmers themselves (GRAIN, 1990).

Indigenous knowledge systems may be adaptive skills of local people usually derived from many years of experience that have been communicated through oral traditions and learned through family members over generations (Thrupp, 1989). They can also be time-tested agricultural and natural resource management practices which gave way for sustainable agriculture (Venkatratnam, 1990). Venkatratnam (1990) went on to state that indigenous knowledge systems can be strategies and technologies developed by local people to cope with the changes in the socio-cultural and environmental conditions or they are practices that are accumulated by farmers due to constant experimentation and innovation According to Roling and Engel (1992), indigenous knowledge systems are trial and error problem-solving approaches by groups of people with an objective to meet the challenges they face in their local environments. Indigenous knowledge systems may appear simple to outsiders but they represent mechanisms to ensure minimal livelihoods for local people (Thrupp, 1989).

Indigenous knowledge systems often are elaborate, and they are adapted to local cultural and environmental conditions (Warren, 1987). Such knowledge systems are tuned to the needs of local people and the quality and quantity of available resources (Pretty and Sandbrook, 1991). They also pertain to various cultural norms, social roles, or physical conditions. The efficiency of indigenous knowledge system lies in the capacity to adapt to changing circumstances (Norguard, 1984).

Rajasekaran (1993) conceived that: (1) agricultural researchers do not investigate the impact of the technologies they develop. They feel that their responsibility ends once the technologies are released to the extension officers. (2) Agricultural extension officers perceive that dissemination of technologies to farmers is their only responsibility. Once the technologies are disseminated to the farmers they are completely satisfied with their jobs, (3) even some enthusiastic extension officers who have tried to bring feedback from the farmers are not encouraged either by the extension administrators or researchers. Hence, feedback from farmers regarding the characteristics of the introduced technologies are rarely recorded (Rajasekaran, 1993).

Agricultural Extension Officers and researchers are usually not aware of local classification systems of farmers regarding soils, crops, livestock, and other natural resources (Dvorak, 1988). During the process of technology development farmers' informal experimentations are not considered as a source of innovation. Despite the fact that there is increased coordination between research and extension officers through periodical extension work, scientific workers' conferences, farmers' innovations are not considered while conducting on-farm research trials (Rajasekaran and Martin, 1990). Farmers are mostly seen as the recipients of technical messages but not originators of either technical knowledge or improved practice (Moris, 1991). Meanwhile, Andean farmers in Peru have classified over 400 varieties of potato developed by them and their ancestors.

Andean small farmers are responsible too for an important technical innovation which is often credited to scientists working at the International Potato Centre (CIP). The scientists noticed that these farmers, like those in Kenya and Nepal, stored potatoes in diffused light rather than in darkness. They tested and refined the technique, and successfully passed it on back to the farmers (GRAIN, 1990). These submissions point out that though farmers may develop some tacit scientific knowledge as a result of experience, research scientists and Extension Officers may not recognize such knowledge.

GRAIN (1990) stated further that farmers have also played a major role in the selection and diffusion of new varieties originally developed in research stations. An example is a case in which a new paddy rice variety, 'Mahsuri,'- rejected by official researchers after poor performance on their experimental stations somehow reached farmers in the Indian state of Andra Pradesh. Farmers tried it and found its performance to be excellent under their conditions, and its use spread to other states. It is now the third most popular variety in India (GRAIN, 1990).

Small scale farmers are often considered as backwards, obstinately conservative, resistant to change, lacking innovative ability and even lazy (International Federation of Agricultural Producers (International Federation of Agriculture Products [IFAP], 1990). According to IFAP (1990), the reasons for these may include lack of understanding of traditional agriculture practices giving rise to myths. It is also because the accomplishments of farmers are often not recognized because they are not recorded in written form or made known. It may also be due to poor involvement of farmers and their organizations in interacting, consolidating, and disseminating what is already known.

According to Careers.co.za (Internet- http://www.careers.co. Za/displaycmetem .asp?strItemTypec=Occupations&strID=), the primary responsibility of an agricultural extension officer is to keep farmers informed about new developments in the agricultural sector. It was further written at the website that an agricultural extension officer needs to use a variety of methods to reach the farmers. For example organizing study groups for farmers, farmer days, demonstrations, lectures and literature as well as informing the media. The agricultural extension officer also needs to make personal visits to farmers to discuss new developments (Careers.co.za, Internet- http://www.careers.co Za/. displaycmetem.asp?strItem Typec= Occupations &strID=). An agricultural officer also propagates farming and development programmes aimed at reaching marginalized farmers or those who have little access to information and extension services. This is done i collaboration with the farming communities, helping them to help themselves to become more self-reliant and independent (Careers.co.za, Internet- http://www. careers.co.Za/ displaycmetem. asp?strItem Typec=Occupations&strID=). McCartney *et al.* (2006) also observed that creating an environment where farmers are supported in an appropriate way enables the continuous improvement and innovation of management practices, processes and performance. McCartney *et al.* (2006) went on to state that when farmers practice continuous improvement and innovation using the better practices process then they can look critically at their situations to identify key opportunities for improvement. For significant improvement in performance there must be a fundamental change in thinking, enabling new ideas and opportunities to be identified, and resulting in different decisions, which can then be converted into action. Creating an environment where farmers are supported in this way enables the continuous improvement and innovation of management practices, processes and performance (McCartney *et al.*, 2006).

The extension officer needs to think about the degree of participation that is appropriate for any programme. He or she also needs to identify strategies for the appropriate level of participation for different sections of the community. In some communities there will be significant population changes over different periods of time which will mean that an extension officer will need to embrace various strategies to achieve the appropriate level of participation. However, researchers consider extension agents and institutions to be ineffective and unclear about their mandate. This makes researchers reluctant to work with them. However, when researchers work with extension agents, they tend to look down upon them and view them as little more than available manual labourers, and this attitude is strongly resented by the extension agents (Kaimowitz, 1992).

One of the major problems facing agricultural extension services in Sub-Saharan Africa is low level of staff education as compared with the education of their research counterparts. This lack of proper education and training hampers research-extension linkage and results in a slow or ineffective diffusion of technology to farmers. Opio-Odongo (2000) observed that as extension services move more to incorporate participatory approaches in rural development, most field-level extension personnel do not have sufficient education to benefit from training or in-service activities. Current agricultural trends, such as those related to population, gender and environmental issues are placing adverse and complex demands on extension staff

(Zinnah *et al*., 1999). Agricultural extension officers are central to facilitating the changes associated with these trends. Therefore it is very important to make available formal training or re-training programmes available to extension workers so that they can conduct independent or group educational projects in their extension areas. This type of hands-on extension training builds upon the concept that experiences are the building blocks of learning (Kolb, 1984).

Chlorophyll fluorescence induction kinetics

According to Baker and Rosenqvist (2004), there is no doubt that measurements of chlorophyll fluorescence, when applied with appropriate care, can provide useful information about leaf photosynthetic performance. Cerovic *et al* (1999) also stated that it has been observed in recent times that ultraviolet light induced chlorophyll fluorescence is a good method for plant monitoring in agricultural and plant sciences applications. Based on the ratios of chlorophyll fluorescence emission spectra intensities at 683 and 731 nm, F683 / F 731, and other significant intensity ratios, this technique can discriminate between normal and stress conditions in vegetation (Chappele *et al*., 1984; Saito *et al*., 1998; Subhash and Mohanan, 1995; Lichtenthaler, 1990). From these measurements, an increase of the ratio F690 / F740 is caused by a lower chlorophyll content and or decline in photosynthesis (Karlson, 1992).

The current study

A review of the literature reveals several points which indicate the importance of cowpea in the diet of people of the world in general and in Africa, more especially, West and Central Africa. However, the literature on cowpea pollination is very limited and even the few that exist are very outdated. Worse of all pollination as a subject appears to be receiving very low attention in Africa for that matter West and Central Africa. This is attested to by Rodger *et al.* (2004) when they stated that a review of African pollination biology showed that relatively little work has been done on pollination biology in Africa, and a very small proportion of pollination relationships have so far been studied. Even much of the research which has been done in Africa on pollination is of an evolutionary nature. Hence very little work has been conducted at the community level and comparatively little applied work, either to agriculture or conservation was encountered (Rodger *et al.*, 2004).

Narrowing the argument to Ghana it appears the situation is worse for it is difficult to come across scholarly publications on pollination in general let alone cowpea pollination. Does the aforementioned development mean that cowpea is entirely self-pollinated and therefore there is no need to do any further research to find out if some level of cross-pollination takes place at all? While it is known that several insects visit different plants for different purposes (Memmott, 1999; Gomez and Zamora, 1999) should it be concluded that no insect visits the cowpea flowers in our environment? Even if there are insects that visit the cowpea flowers in our environment what role do they play on the flowers? These are questions that scholarly literature is silent on in our Ghanaian environment. Meanwhile Food and Agriculture Organization (FAO) Corporate Document Repository (Internet-http://www. fao/ docrep/006/y5110e/y5iioe03.htm) asserted that pollination is necessary for all seed and fruit production by flowering plants. They further stated that transfer of pollen among flowers to allow their reproduction is a very vital mechanism for maintaining life on earth.

Apart from unraveling the truth behind what insects visit cowpea flowers and to find out what they do on the flowers lies the concern about what level of knowledge cowpea farmers and Agricultural Extension officers have about cowpea pollination, chemical applications in the cowpea agro-ecosystem and the effects on probable cowpea pollinators. Meanwhile, the argument is advanced that in general farmers' innovations and their accumulated knowledge has provided the foundations for thousands of years of agricultural development which has been crucial for "modern" agriculture, especially in the arena of plant genetic resource use and conservation (GRAIN, 1990). This is commonly referred to as indigenous knowledge system (Thrupp, 1989). Such indigenous knowledge systems, it is said can be time-tested agricultural and natural resource management practices which gave way for sustainable agriculture (Venkatratnam, 1990) suggesting that such practices may not be sustainable but useful source of information that science can build upon. Here, the assumption therefore is that the farmers already have some kind of knowledge from the indigenous system that may apply to cowpea pollination and pollinator services. However, it is very baffling to note also that the same farmers most often indiscriminately apply chemical pesticides to the detriment of useful insects including pollinators. So, is it justified to say that the farmers already know much about pollination and pollination services in cowpea agro-ecosystems? A further point worth advancing is that since the pollination literature in our environment is so scanty and research scientists themselves are confused about the mode of pollination of cowpea can it be said that the Agricultural Extension Officers from Ghana are abreast with the facts surrounding cowpea pollination and pollination services? These are the issues and questions that this research attempted to find answers to.

The study mainly tried to find out the knowledge that cowpea farmers and Agricultural Extension officers possess about the role of cowpea insect flower visitors and the effects of pesticide applications on such insects in three districts in Central Region of Ghana. It further involved field investigation of the role of insect flower insect visitors in cowpea agro-ecosystems in the three districts.

CHAPTER THREE

METHODOLOGY

The study area

The study was located in Agona, Gomoa and Ewutu-Effutu-Senya districts in the Central Region of Ghana. Ghana is bordered on the East by Togo, on the West by Cote d'Ivoir, on the North by Burkina Faso and on the South by the Atlantic Ocean (Plate 1). The country occupies an area of 238,538km^2. There are 10 administrative regions in Ghana. One of such administrative regions is the Central Region.

Plate 1: Map of Ghana (not to scale).

The Central Region is bordered by the Ashanti and Eastern regions to the North, Western region to the West, Greater Accra region to the East and the Atlantic Ocean to the South (Plate 2). Central region occupies an area of 9,826 km². There are 13 administrative districts in the region (at the time of this study) (Law, 2008). The study covered three of the districts, namely, Agona, Gomoa and Ewutu-Effutu-Senya districts (Plate 3). The capital of Agona district is Swedru. The district occupies an area of 632km^2. The capital of Gomoa district is Apam and the district occupies an area of 891 km^2. The capital of Awutu-Effutu-Senya district is Winneba and the district occupies a space of 786 km^2 (United States of America Department of State Bureau of African Affairs, 2009).

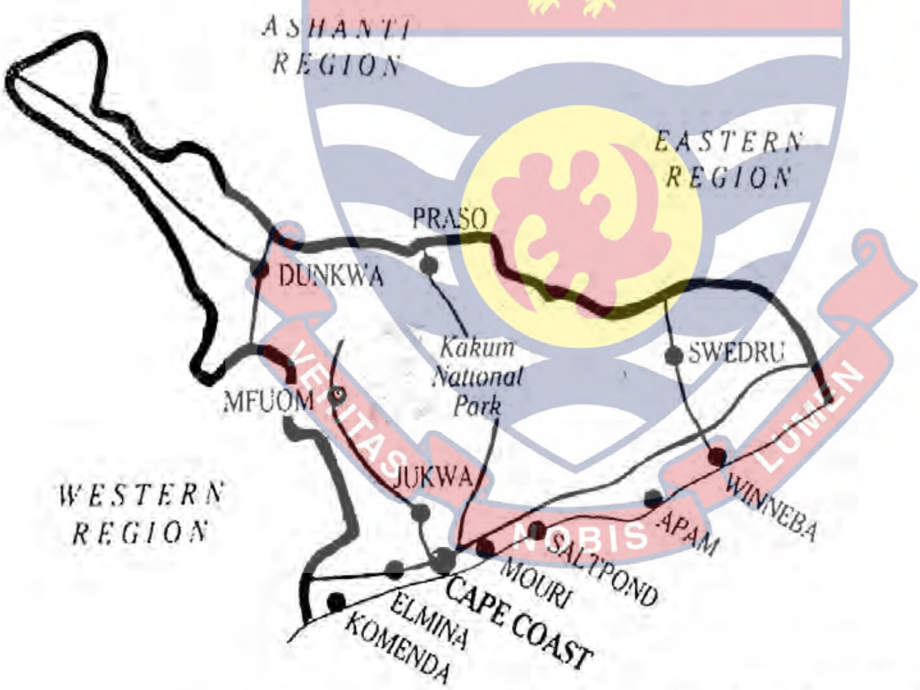


Plate 2: Map of Central Region showing some of its boundaries with other regions (Not to scale)

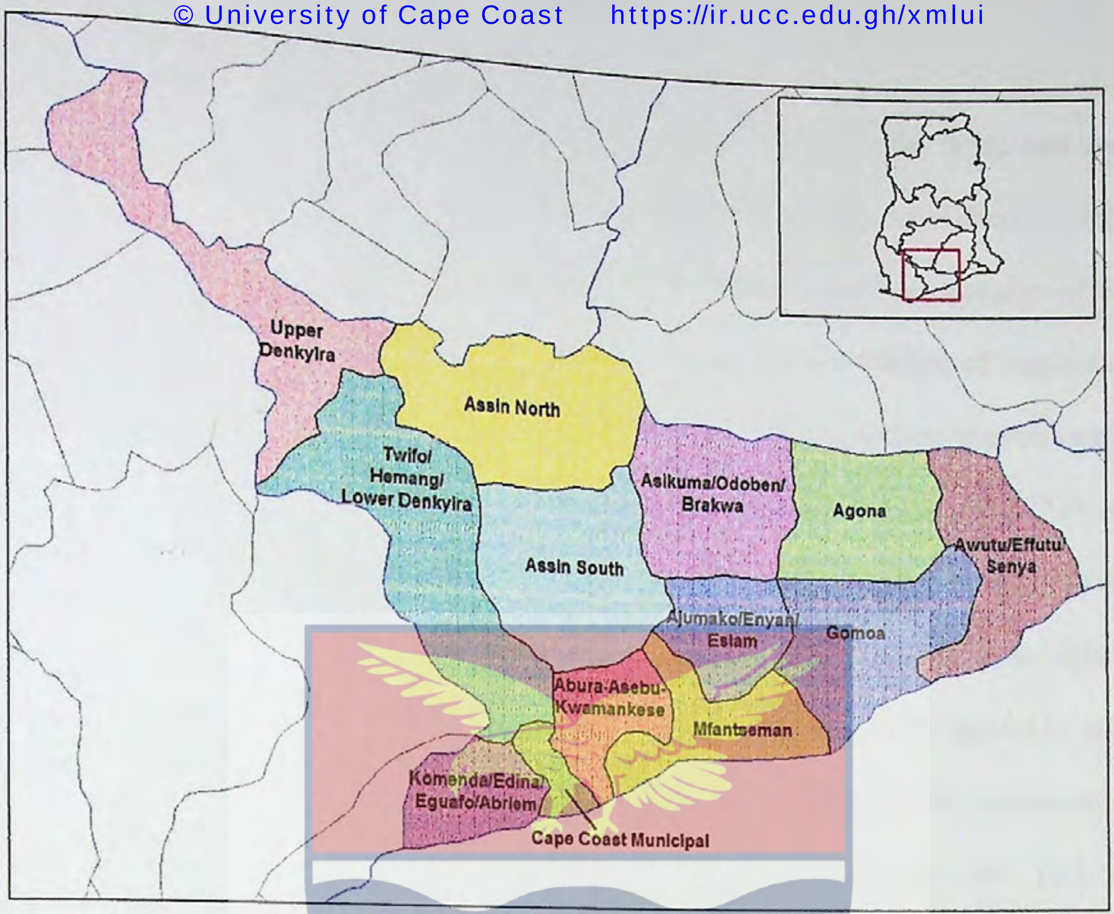


Plate 3: Map of Central Region showing the various districts at the time of the study (not to scale)

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors and the effects of pesticide control measures on them

The population

The population of the study consisted of cowpea farmers and Agricultural Extension Officers of the Ministry of Food and Agriculture (MOFA) from three administrative districts (Agona, Ewutu – Effutu - Senya and Gomoa) in the Central Region of Ghana. The total number of Extension Officers from the three districts was 104. The breakdown from the various districts were as follows; 32 Officers from Agona District, 30 from Gomoa District, and 42 from Ewutu- Effutu- Senya District.

The instrument

The instrument for the study was questionnaire, which was developed using information from reviewed literature. The first section of the instrument collected information pertaining to the personal data of the farmers and the extension officers (respondents). The second section collected data on the knowledge of respondents about cowpea flower visitors. Finally, the third section sought information on cowpea pest control in relation to cowpea flower visitors. The instrument contained 27 closed-ended and four open-ended items. The closed-ended items mostly involved multiple choices where respondents were expected to choose the correct option. In order to make the items as easy as possible for respondents to understand and respond to, seven of the items demanded the respondents to simply agree or disagree with statements. In this case ratings of 1 = disagreed and 2 = agreed were used for the raw data. To a very large extent both cowpea farmers and extension officers responded to the same items (questions). However, three of the items were restricted to the farmers and seven to the Extension Officers (See appendix 1). The rest of the items were open to both cowpea farmers and the Extension Officers.

Sample and sampling

The instrument was pilot tested with 20 farmers and 10 Agricultural Extension Officers. Those items found to be inappropriate were either modified or dropped before moving on to administer the instrument to respondents

Before administering the questionnaire to cowpea farmers the researcher went round 15 towns and villages in Agona, Ewutu-Effutu-Senya and Gomoa districts to find out where cowpea farming was being done (Table 1). Ten towns/villages from which some serious cowpea farmers were found were selected (Table 2). Farms belonging to farmers from these ten towns/villages ranged between one quarter (1/4) to one (1) acre in size. Proportional stratified random sampling was used where 33 farmers were sampled from Agona district, another 33 from Awutu-Effutu-Senya district and 44 farmers from Gomoa district. Therefore, in all 110 cowpea farmers were sampled. They were then given the questionnaires to respond to. Those farmers who were literates responded to the items in the questionnaire without any assistance from the researcher. For those farmers who were illiterates or semi-literates, the items in the questionnaire were interpreted to them in Fante. The answers provided were ticked or written by the researcher at the appropriate place on the questionnaire.

Table 1: Towns/villages from which cowpea farmers were identified

AGONA DISTRICT	GOMOA DISTRICT	AWUTU-EFFUTU-SENYA DISTRICT
Swedru	Afransi	Bontrase
Asafo	Gomoa Oboasi	Winneba Junction
Kotokoli Zongo	Gomoa Oseadze	Ofaakor
Nyakrom	Dewurampong	Ateitu
Nsaba	Gomoa Ankamu	Atekyedu

Table 2: Towns/villages from which cowpea farmers were selected

AGONA DISTRICT	GOMOA DISTRICT	AWUTU-EFFUTU-SENYA DISTRICT
Asafo	Afransi	Bontrase
Kotokoli Zongo	Gomoa Oboasi	Ateitu
Nsaba	Dewurampong	Atekyedu
	Gomoa Ankamu	

The communities from which the Agricultural Extension Officers were selected from the three districts have been presented in table 3. For the Extension Officers also proportional random sampling was used to select the respondents from the three districts. Therefore, 14 Officers were sampled from Gomoa district (out of total of 30), 20 Officers from Ewutu-Effutu-Senya district (out of 42 officers) and 16 Officers from Agona district (out of 32 officers). In each Ministry of Food and Agriculture (MOFA) District Office, one Officer was put in charge of administering the questionnaires. The Officer randomly selected respondents from the district office as well as those in the communities who visited the offices. For those who visited the offices the lead Officer ensured that any of them that he/she met in the office was given a copy of the questionnaire. This was done until the required number from each district was obtained. The lead Officer again collected the filled questionnaires back from his/her colleagues. The researcher later went back to each District Office to collect the filled questionnaires. In all, 50 Agricultural Extension Officers were issued with the questionnaires.

Table 3: Communities from which Agricultural Extension Officers were sampled

AGONA DISTRICT	GOMOA DISTRICT	AWUTU-EFFUTU-SENYA DISTRICT
Swedru	Akropong No 2	Bontrase
Kwanyako	Abasa	Winneba
Mensakrom	Mangoase	Ofaakor
Mankrong	Afransi	
Asafo	Oboasi	
Jacob	Akotsi	
Bobikuma	Ankamu	
Nyakrom	Oseadze	
Abodom	Manso	
Akwakwaa	Dewurampong	
Nkum	Aboso	

Analysis of data

The data were analyzed using descriptive and inferential statistics. The descriptive statistics used were means, frequency distributions, and percentages. In some cases chi-square analysis was used to compare the differences in the responses between the observed and expected values. For items demanding 'agree' or 'disagree with' statements, analysis was done such that ratings of 1-1.4 = majority disagreed, 1.50 = 50% agreed and1.6- 2 = majority agreed were used.

Survey of farms

Thirteen cowpea farms in the three districts (Agona, Ewutu – Effutu - Senya and Gomoa) in the Central Region were surveyed for cowpea insect flower visitors when about half of the plant population started flowering (November, 2005). The selected farms were at least one kilometre apart. The main criteria for selecting a farm was that the farm was pure cowpea stand (not mixed with any other crop), a farm of size at least approximately 6m^2, and two farms were at least one to ten kilometers apart. Since the main objective of the survey was to have an idea of what types of insects could visit cowpea flowers, the variety of cowpea sown by the farmers was not taken into consideration. This was so, also because it was difficult to determine the exact variety of cowpea sown by the farmers by merely looking at the flowers and leaves. Farmers mostly do not sow the cowpea in rows so this was not a criterion.

Fifty flowers were selected randomly at 3-metre intervals in each farm. All the insects observed were recorded according to the specific part of the flower where they were observed (on petals, on the tip of the stigma and inside the flower) (Plates 5 – 10). Samples of insect visitors observed on the flowers were collected and identified. The frequency and percentage frequency of occurrence of each species on specific parts of the flowers were determined. The total frequency and percentage frequency of occurrence of each insect species was determined by pooling the means pertaining to the three positions on the flowers (on petals, on the tip of the stigma and inside the flowers). Chi-square (χ^2) analysis was done for the total frequencies.

Field experiments

A cowpea farm was established about one kilometer away from Ekwamkrom in the Gomoa District. Ekwamkrom is about one kilometer away from Agona Swedru on the Winneba-Swedru highway. The experimental site was surrounded by a mixture of elephant grass and *Chromolaena odorata* commonly known in Ghana as Acheampong weed. Ekwamkrom is mostly surrounded by transition forest. The farm was 15 by 25 metres in dimension.

It was observed that cowpea farmers in the experimental area do major rainy season sowing between April and June while the minor rainy season's sowing is done between August and October. Ghana/CIDA Development Project (1988) and Adu-Dapaah *et al.* (2005) stated that in the transition forest zone sowing should be done from April to May in the major rainy season and from August to September in the minor rainy season. Since the experimental site was surrounded more by transition forest than forest itself the major rainy season sowing was done on 3rd April, 2006 and in the minor rainy season sowing took place on 21st September, 2006. It was also observed that farmers preferred a variety commonly called black eye to the nationally recommended varieties. A survey of bean sellers in the area revealed that black eye is commonly consumed by the public. The reasons given for this were that the variety is easy to cook and swells very much. Hence, black eye was the variety used for this experiment. The seeds were purchased from seed sellers. Three seeds were sown about 2.5cm deep per hole. Seeds were sown 30 cm between plants and 90 cm between rows. When seedlings were two weeks old the plants were thinned to two per hole. Plants depended on natural rainfall. Throughout the experiment, there was no pesticide application.

When the plants started flowering, on each day between 100 and 150 flower buds were covered with fine-mesh net such that no organism could get in when the flower opened (Plate 4). In order to prevent ants from entering the fine-mesh net glue was applied to the ends tied with rubber bands. Observation for insect flower visitors were made every other day. Purseglove (1974) observed that cowpea flowers open early in the morning, close before noon and fall the same day. Hence, observation was made between 6am and 12 mid-day. On days that observations were made, matured opened flowers that were not covered were removed so that the insect visitors could focus almost entirely on those that were targeted for the experiment. The fine-mesh net was taken off flowers in batches of three in a row (the cowpea was planted in lines). Flowers were selected such that two selected flowers were three meters away from each other.

Plate 4: Flowers covered with fine-mesh net (X 3)

Observation for insect flower visitors on the petals, tip of stigma and inside the flowers (Plates 5 – 9) was made on the three flowers concurrently. Whenever an insect landed at the tip of the stigma of a flower (Plate 10) that particular flower was re-covered. When at least two uncovered flowers had been visited by insects and re-covered another two were uncovered to make it three once again. All flowers re-covered after a visit by an insect were observed for fruit formation (Plate 11) on the third day. Uncovered flowers that were not visited by insects and those visited by other organisms apart from insects were ignored.

Plate 5: A cowpea flower with an unidentified insect (arrowed) on a petal (X 3)

Plate 6: A cowpea flower with a dipteran (arrowed) on the petals (X 3)

Plate 7: A cowpea flower with an unidentified Lepidopteran (arrowed) on the petals (X 3)

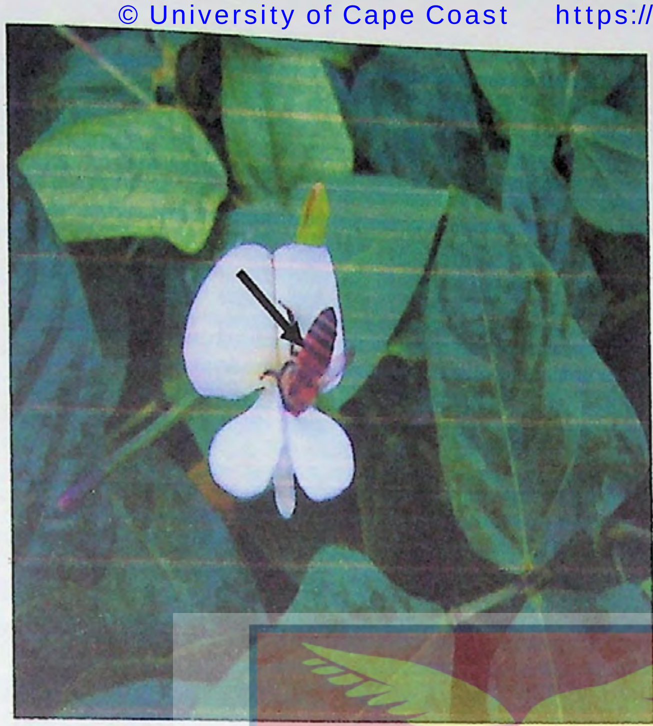


Plate 8: A cowpea flower with *Apis mellifera adansoni* (arrowed) piercing its tongue into the ovary (X 3)

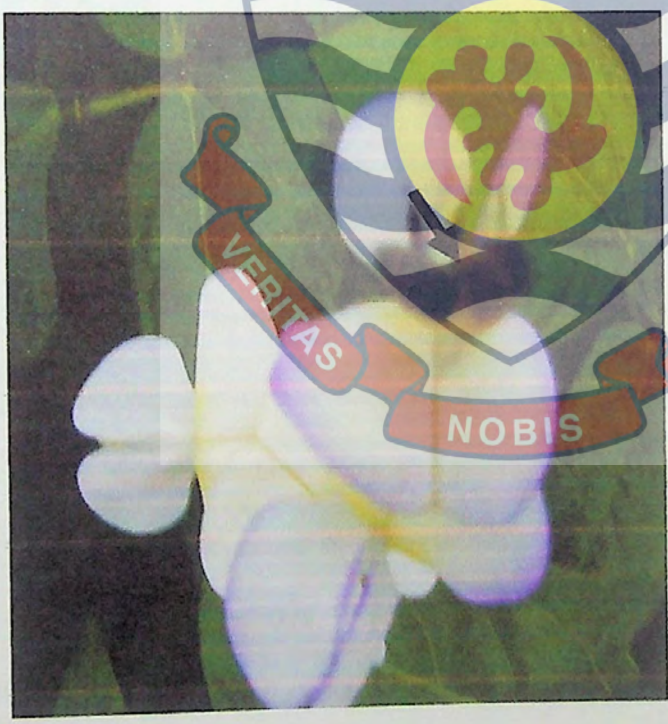


Plate 9: A cowpea flower with *Apis mellifera adansoni* (arrowed) on the petals (X 3)

Plate 10: A cowpea flower with *Megachile* sp (arrowed) sitting on the tip of the stigma (X 3)

On a day that observation was made for fruit formation a number of flowers that were not exposed at all were also uncovered and observation made for fruit formation. The flowers that were not exposed to any organism served as control. Always the number of control flowers that were observed for fruit formation on any day was equal to the number of flowers observed for fruit formation for a particular insect species with the highest number of visited flowers the previous day. These served as the standard. Flowers visited by insects that formed fruits were assumed to have been pollinated by the visitors concerned. Specimens of the insects were collected and identified.

At least two flowers were covered on each plant. However, only one of the covered flowers on each plant was opened for observation while the second flower was still covered. The covered or unexposed flowers served as control. Hence, it was ensured that in most cases when there was an insect visited flower being observed for fruit set on a plant, on the same plant there was a control flower being observed for fruit formation. This was largely to take care of probable differences in soil conditions.

Observation of flowers for insect visitors was done each other day. Similarly, observation for fruit formation was done each other day. Therefore, on the day that observation for flower insect visitors was being done observation for fruit formation was not done. In the major rainy season in 2006, observation was made for three weeks and two weeks later when the plants started re-flowering observation was made for one week. However, in the minor rainy season in 2006 the plants died off after sampling for three weeks. Therefore there was no other sampling after three weeks.

The fruit sets for flowers visited by different insects and control flowers (Plate 11) were counted and tagged until the fruits were completely developed and matured (Plate 12). The fruit sets were monitored to find out which ones successfully formed pods (Plate 12) and those that failed to form pods (fruit abortion). The number of fruits that successfully formed pods as well as those that aborted was determined.

The likelihood of the visitors as pollinators was estimated by comparing yield of flowers visited by insects with that of control flowers. Five days after initiation of ripening, pods were matured to be harvested without being vulnerable to insects and other pests. Hence, each ripe pod was harvested five days after initiation of ripening. Therefore, the fifth day for harvesting served as a standard. Harvested pods were sun-dried for seven days and kept in a clean and dry room. Seeds in the dry pods were then removed for yield assessment. Yield was assessed by counting the number of pods and the number of beans (seeds) formed per pod for each visitor and the control flowers.

Plate 11: Cowpea flowers developing into fruits (X 4)

Plate 12: Developing cowpea pods (X 3)

Due to the fact that in the major rainy season of 2006, majority of the pods became rotten just before ripening, seed length and seed circumference were not determined. However, the number of seeds per pod was determined for control flowers and flowers visited by *Xylocopa calens* by counting the space occupied by the seeds in the pods. In the minor rainy season of 2006 however, seed length (in cm) and seed circumference (in cm) were determined. The length of each seed was measured using a pair of compasses and ruler. The compass was used to take the length of the seed at the two ends. The compass was then put on a ruler to determine the length of the seed in centimeters. The circumference of each seed was measured using a fine thread, compass and ruler. The fine thread was rolled round the middle of each seed. The length of the fine thread that covered the circumference of the seed was stretched and a compass stretched on it. The compass was then put on a ruler to determine the circumference of the seed in centimeters. Seed length and circumference were used to assess the size of the seeds. Since the experimental farm was about one kilometer away from Agona Swedru weather station, daily rainfall, temperature, and relative humidity figures read three times a day (6.00am, 12.00 noon and 6.00pm) were collected from the weather station The average weekly rainfall, temperature and relative humidity figures were determined.

Data analysis

The percentage occurrence of insects on flowers.

The number of times each insect was observed on a particular part of the flower was recorded. The percentage occurrence of each insect on a particular part of the flower was then determined. This was done by dividing the number of times each insect was observed on a particular part of the flower by the total number of times insects were observed on the flowers multiplied by hundred. The total number of each type of insect species collected from the flowers was also determined and the percentages of occurrence determined by dividing each total by the total number of insects collected multiplied by hundred. Counts were analyzed by using chi-square (χ^2) to determine the differences between the observed and the expected values. This was done by using contingency tables (Everitt, 1977; Sanders and Smidt, 2000).

Percentage fruit set and failure

The number of fruits set for each type of insect and the control were also determined. Similarly, the number of flowers failing to develop into fruits for each insect as well as the control was determined by counting. In each case, the percentage fruit set and fruit failure for each insect and control was then calculated by dividing the number of flowers re-covered for each insect and the corresponding control flowers by the total number of flowers counted for both control and insect visited flowers multiplied by hundred. Here also, counts were analyzed by using χ^2 to determine the differences between the observed and the expected values by using contingency tables (Everitt, 1977; Sanders and Smidt, 2000).

Percentage pod development and failure

The number of pods formed from fruits as well as number of fruits failing to develop into pods for each insect species and the control was also determined. The percentage number of pods developed was calculated by dividing the total number of pods formed for each insect visited flower and the control by the total number of fruits formed multiplied by hundred. Also, the percentage number of fruits failing to form pods was calculated by diving the total number of fruits failing to form pods for each insect visited flower and the control flowers by the total number of fruits formed multiplied by hundred. Chi-square analysis was done by using contingency table.

Percentage number of pods in relation to number of seeds per pod

The number of seeds from each pod for each insect visited flower and control flowers was determined. For convenience, the number of seeds per pod was pre-grouped as 1-3 seeds per pod, 4-6 seeds per pod, 7-9 seeds per pod, 10-12 seeds per pod and 13+ seeds per pod. The total number of pods from which particular grouping of number of seeds per pod was collected was then determined. The percentage number of pods for each grouping of number of seeds per pod was calculated by dividing the number of pods per seed group by the total number of pods multiplied by hundred. The differences between the observed and expected counts were compared using chi-square analysis.

Percentage number of seeds per seed length

Here also, for convenience, the seed length was pre-grouped as 0.6-0.8cm per seed, 0.9-1.1cm per seed, and 1.2+cm per seed. The number of seeds having length falling under each grouping was counted. The percentage number of seeds with each grouping of seed length for control and *Megachile* visited flowers was determined.

Percentage number of seeds per seed circumference

It was noticed that seed circumference ranged between 1 to 2.5cm. Hence, the circumference was pre-grouped 1-1.5cm per seed, 1.6-2.0cm per seed, and 2.1-25cm per seed. The number of seeds whose circumference fell under each grouping was determined. The percentage number of seeds with each grouping was then calculated by dividing the number of seeds with each group of circumference by the total number of seeds multiplied by hundred.

Relationship between weekly rainfall, temperature and relative humidity figures and fruit formation

Mean weekly rainfall, temperature, and relative humidity figures were calculated from the daily figures obtained from the weather station (read for three times a day at 6.00am, 12.00noon and 6.00pm). Graphs were drawn relating the weekly rainfall, temperature, and relative humidity figures to fruit formation and the graphs interpreted.

Experiment with seeds from experimental farm during the minor rainy season – morphological studies of progenies

The seeds obtained from the pods developed from flowers visited by *Megachile* sp and control flowers in the experimental farm during the minor rainy season of 2006 were sown again in May, 2007. This was so because it was only flowers visited by *Megachile* sp that produced pods bearing enough number of seeds that could be used alongside seeds obtained from pods developed from control flowers. Seeds were sown on a plot of land 16 by 45 meters in dimension. The plot of land was demarcated into 12 smaller plots and for the purpose of this study termed as blocks (six each for seeds obtained from control flowers and six for seeds obtained from flowers visited by *Megachile*). Each block was 1.33m by 3.75m in dimension and made up of two rows. For the purpose of this study the two rows were the two lines in which the seeds were sown. Plot size of 16 by 45m was selected because that is the size that can take care of the number of seeds available for the experiment. Therefore, for each type of progeny, there were a total of 12 rows. Seeds from control flowers and those from flowers visited by *Megachile* sp. were sown on alternating blocks. For the sake of this study cowpea plants that developed from seeds obtained from flowers not exposed to any organism were termed as progenies of control and those developed from seeds obtained from flowers visited by *Megachile* sp. were termed progenies of *Megachile* visited flowers.

Seeds were sown 100cm between rows and 40cm between hills. Each row was made up of eight hills and three seeds were sown per hole in a hill about 2.5 cm deep. After germination, plants were thinned to two seedlings per hill in cases where all the three seeds germinated. The following were then determined and compared:

- the initiation and number of flowers,
- leaf surface area,
- chlorophyll fluorescence induction kinetics,
- total number of pods per block for each treatment, number of seeds per pod, seed length and seed circumference,
- nodulation of roots,
- nutrient (Starch, Calcium, Phosphorus, Fibre and Protein) level of seeds of the progenies

Flower initiation and number of flowers

The plants were monitored until the day that the first flower emerged. That day was taken note of. From the day the first flower was observed, six hills (holes) per block were purposively selected making sure that hills that had two plants were selected. Therefore, there were 12 selected plants per block. Fully developed flowers on each of the 12 selected plants on each block were counted every morning between 6 and 7 am. Counting of flowers was done for eight weeks. After the eighth week the total number of flowers for each block was determined. The mean number of flowers per week for progenies of control as well as progenies of *Megachile* visited flowers was determined. The means were used to draw bar graphs against the week and interpreted. The means for both progenies were compared using paired t-test.

Determination of leaf area

Leaf area was determined by tracing twenty five leaves from five plants from each block for the progenies of the control as well as *Megachile* visited flowers on graph sheets. Selection of leaves was standardized by starting from the fourth open leaf below the apical bud downwards each branch. Five leaves were then selected starting from the fourth counted leaf. The five selected leaves were then traced on graph sheet. The surface area of each leaf was then determined. The mean leaf area per plant per block was then calculated. Means were used to draw bar graph. Means of control and *Megachile* visited flowers were compared by using paired t-test.

Determination of chlorophyll fluorescence induction kinetics

Chlorophyll fluorescence induction kinetics was used to assess the photosynthetic performance of the leaves of the progenies of the control and progenies of *Megachile* visited flowers. Fifteen completely developed cowpea leaves were obtained from five different plants forming the progenies of *Megachile* visited flowers as well as control for the measurements. To select a leaf, three opened leaves were counted just below the terminal or apical bud downwards each branch. The purpose of counting three opened leaves from the terminal bud was to achieve uniformity and standardization. The third, fourth, and fifth leaves from the apex of each branch were then picked for the measurements in each case for progenies of the control and *Megachile* visited flowers. Complete spectra using a compact continuous violet laser diode fluorosensor (Gustafsson *et al.*, 2000; Anderson *et al.*, 2004) emitting at 396 nm were used as an initial test for chlorophyll fluorescence (ChlF) wavelength selection.

The peak wavelengths of the ChlF, were selected for chlorophyll fluorescence induction kinetics (Kautsky effect). In the Kautsky effect, the leaves were illuminated for 300 seconds using the same compact continuous violet laser diode fluorosensor (Gustafsson *et al.*, 2000; Anderson *et al.*, 2004) after the leaves had been pre-darkened for 20 minutes. The leaves were placed on a non-fluorescence aluminum plate to reduce possible spectra noise.

During the chlorophyll fluorescence induction kinetics the fluorescence intensities of two peaks and their ratios were recorded within the period of observation. It was the slow part of the Kautsky's effect from a maximum intensity level (Fmax) followed by a slow fluorescence decay until a steady state (Fs) at 300s was recorded. The same processes were done for the other leaves. In all thirty measurements were taken for the two classes. The whole process was presented graphically, then from the slow fluorescence decrease (Fd = Fmax-Fs) the fluorescence decrease ratio (Rfd = Fd/Fs) of the leaf was calculated. At the same time the changes in the F685/F740 during the different phases of the induction kinetics were followed. A graph of average fluorescence intensity (a.u) against time (in sec) was drawn and interpreted.

Number of pods

Five days after initiation of ripening, pods were matured to be harvested without being vulnerable to insects and other pests. Therefore, the fifth day for harvesting served as a standard. Hence, each ripe pod was harvested from the 12 selected plants on each block five days after initiation of ripening. Pods were harvested by hand picking. Harvested pods were sun-dried for seven days and kept in a clean and dry room. After harvesting and drying, all pods for each block for the progenies of control as well as *Megachile* visited flowers were pooled together and counted to determine the total number of pods per block per each type of progeny. The expected number of pods was then calculated using contingency table. The observed and expected number of pods for the progenies of control and flowers visited by *Megachile* were then compared using contingency table to do chi-square analysis (Everitt, 1977).

Determination of number of seeds per pod

Seeds from dry pods were removed. For convenience, number of seeds per pod were pre-grouped as follows: 1 – 3 seeds per pod, 4 – 6 seeds per pod, 7 – 9 seeds per pod, 10 – 12 seeds per pod , and 13 – 15 seeds per pod. The number of seeds per pod was determined. The number of pods having number of seeds falling under each of the above groupings was recorded. The differences between observed and expected number of seeds per pod for the progenies of the control and flowers visited by *Megachile* sp. were compared by using Chi-square analysis.

Also, the total number of seeds out of 70 pods and mean number of seeds per pod per block for the progenies of the control as well as flowers visited by *Megachile* sp.were determined. Seventy pods were selected as a standard. The differences between the total number of observed and expected seeds of the progenies of the control and flowers visited by *Megachile* sp. were determined using chi-square analysis. Also, the differences between the mean number of seeds for the progenies of the control and *Megachile* visited flowers were determined by using paired t-test.

Determination of seed length and seed circumference

Length and circumference of each seed was also determined. Here also, for convenience, seed length was grouped as 0.6 – 0.8 cm per seed, 0.9 – 1.1 cm per seed and 1.2+cm per seed while seed circumference was grouped as 1.0 – 1.5 cm per seed, 1.6 – 2.0 cm per seed and 2.1 – 2.5 cm per seed. The percentage number of seeds per seed length as well as percentage number of seeds per seed circumference for the progenies of the control as well as flowers visited by *Megachile* sp. was determined. The percentage seed length for each type of progeny was determined by dividing the total number of seeds bearing particular length by total number of seeds for the particular type of progeny multiplied by 100. The percentage seed circumference for each type of progeny was also determined by dividing the total number of seeds bearing particular circumference by the total number of seeds for the particular type of progeny multiplied by 100. Bar graphs of the percentage number of seeds against seed length and percentage number of seeds against seed circumference were drawn and interpreted descriptively.

Assessment of nodulation of roots

After harvesting the pods, the 12 selected plants on each block were uprooted. The number of nodules on the roots of each plant was then counted. The average number of nodules per block for the progenies of the control as well as progenies of flowers visited by *Megachile* sp. was also calculated. The means were used to draw bar graphs for analysis. The differences between the means for the progenies of the control and progenies of *Megachile* visited flowers were determined by using paired t-test.

Nutrient analysis of seeds

Seeds of the progenies of the control and progenies of flowers visited by *Megachile* sp. were oven-dried and ground. This was followed by weighing 0.2g of each ground specimen into a digestion tube. After that, 4.4ml of digestion mixture was added and digested for 2 hours. The digest was diluted into a 100ml of distilled water.

The solution was then used for the determination of nitrogen (protein), calcium and phosphorus

Protein (Kjeldahl method)

An aliquot of the diluted digest was taken and distilled with alkali mixture for nitrogen using boric acid indicator. The distillate was titrated with 0.07 (1 / 140) M HCl. If T ml of 0.07M HCl were required for the titration, then

$$\% N = \frac{T\ (ml) \times Solution\ volume}{10^2 \times aliquot \times sample}$$

Therefore % protein = % N x 6.25 (Allen *et al.*, 1974). The values obtained were multiplied by 10,000 to convert them into milligrams per kilogramme (Mg / kg)

Calcium, using the flame photometer

A stock solution (1000 ug/ml Ca) was prepared by dissolving 2.4973g of dry $CaCO_3$ in 200 ml water containing 5ml concentrated HCl and made up to 1 litre. Out of this, solutions with the concentrations 0, 10, 20, 30 40, and 50 ug/ml Ca were made. The remaining solution prepared of which part was used for protein determination was then used for the determination of calcium also. The flame photometer was switched on and warmed for 15 minutes. The calcium filter was then selected. The system of the set up was flushed with distilled water. The standards were then aspirated and their emissions recorded. The samples were also aspirated and their emissions recorded. With the concentrations and emissions of the standards a calibration curve was plotted. Using the emissions of the samples, the concentrations (c ug/ml) of calcium in the samples were extrapolated from the calibration curve. (Allen *et al.*, 1974).

$$\text{Therefore } \% Ca = \frac{c\ (ug/ml) \times solution\ volume}{10^4 \times sample\ weight}$$

The values obtained were converted into Mg/kg by multiplying by 10, 000.

Phosphorus

A standard solution of phosphorus (P) was prepared in 25 ml volumetric flasks. Aliquot of dissolved digest was taken into 25 ml volumetric flasks. After that 4 ml of colour forming reagent was added to the standards and samples. More water was added to the 25 ml mark and the mixture shaken. Colour development was allowed over 15 minutes. The absorbances of the standards and samples were determined at 882nm using a spectrophotometer. A standard curve was drawn using the concentration of the standards and their absorbances. The concentration of the aliquot was extrapolated with the absorbances of the samples in the 25 ml from the standard curve. The values were converted into Mg/kg. (Allen *et al.*, 1974).

Soluble carbohydrate

Extraction:- Fifty miligrammes (50 mg) of ground sample was weighed into 100 ml conical flask and then 30 ml of distilled water was added and simmered gently on a hot plate for 2 hours. The mixture was allowed to cool slightly and filtered through number 44 Whatman paper into 50ml volumetric flask. The paper was washed and the mixture diluted to 50ml mark when cooled.

Colour development:- Two millilitres (2 ml) of each of two standard carbohydrate solutions was pipetted into a set of boiling tubes. Then, 2 ml of the extract was pipetted into boiling tubes and 10 ml of anthrone reagent was rapidly added to both standards and samples. The tubes were immersed in running cold water (Or ice bath). The tubes were then placed in boiling water in a darkened fume cupboard and boiled for 10 minutes. The tubes were then placed in cold water and allowed to cool. The optical density was then measured at 625 nm. A calibration graph was prepared from the standard solutions and used to obtain mg glucose in the sample aliquot.

$$\text{Therefore \% Soluble Carbohydrate} = \frac{\text{C (mg) x extract volume}}{\text{10 x aliquot x sample weight}}$$

The values obtained were converted into Mg/kg (Allen *et al*., 1974)

Crude fibre

Acid Hydrolysis:- One gramme (1 g) of ground sample was weighed into 600 ml Pyrex beaker. After that 100 ml of boiling 1.25% Sulphuric acid (H_2SO_4) was added. It was covered with a watch glass and boiled gently on a hot plate for 30 minutes. The acid was removed by suction. The mixture was washed three times with 50 ml boiling water.

Alkali Extraction: - Hundred millilitres (100 ml) of boiling 1.25% Sodium hydroxide (NaOH) was added to the mixture. The set up was covered with watch glass and boiled gently on hot plate for 30 minutes. The alkali was removed through suction. The mixture was then washed with 25 ml boiling 1.25% H_2SO_4. It was then washed two times with 50 ml boiling water. The contents of the beaker were washed into a weighed glass crucible using 50 ml boiling water. The content was further washed with 30 ml ethanol. The crucible and its contents were dried for three hours at 105°C. It was then cooled and weighed. The weight difference gave the fibre content. (Allen *et al*., 1974)

CHAPTER FOUR

RESULTS

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors within the cowpea agro-ecosystems

Out of the 110 questionnaires given out to the farmers 104 (94.6%) were returned whilst 44 (88%) out of 50 were retrieved from Extension Officers. Majority of the farmers (80.8%) and Agricultural Extension Officers (86.4) were males (Fig.1). The farmers were mainly between 15 and 55 years of age whilst majority of the Agricultural Extension Officers were between 26 and 45 years of age (Fig. 2).

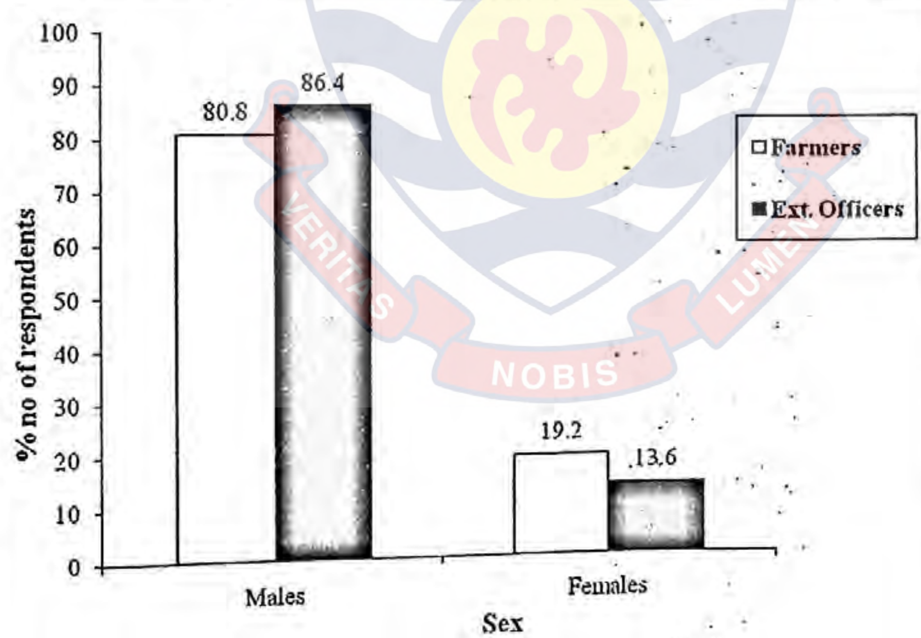


Fig. 1: Sex distribution of respondents

Some other personal data of cowpea farmers are presented in Table 4. A large number of the farmers (43.3%) attended secondary school, middle / junior secondary school (25.0%) and the university (19.3%). The differences between the observed and expected frequencies were very highly significant (χ^2 = 103.82, P = 0.001). For experience, 71.2% of the farmers have been cultivating cowpea for between 1 and 5 years whilst 15.4% have been doing it for 6-10 years. In terms of acreage 48.1% of the farmers do less than 1 acre a year whilst 38.5% do 1-5 acres per year whereas 11.5% do less than 16 acres. The differences between the observed and expected responses were very highly significant (χ^2 = 137.41, P = 0.001).

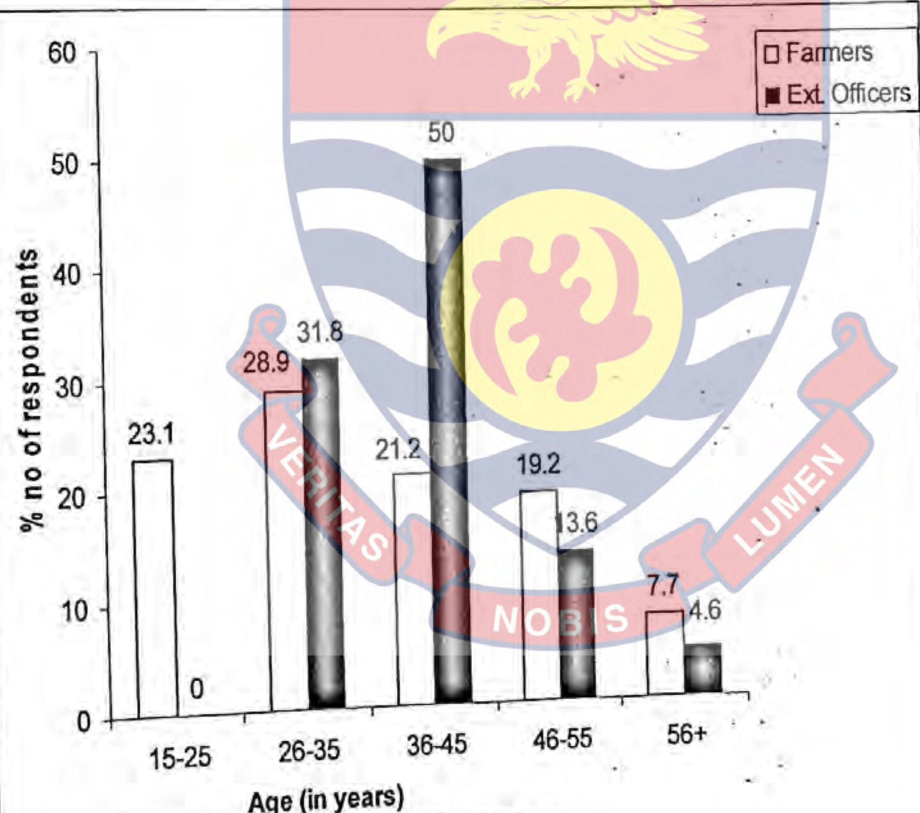


Fig. 2: Age distribution of respondents

Table 4: Personal data of cowpea farmers (N=104)

Item / response	Freq.	% Freq
What is your highest level of education?		
No formal education	0	0
Primary school	2	1.9
Middle school/ Junior secondary school	26	25.0
Secondary school	44	43.3
Agricultural Institute	6	5.8
Vocational / Technical school	6	5.8
University / Polytechnic	20	19.3
$\chi^2 = 103.82$		
For how long have you been doing cowpea farming (in years)?		
1 – 5	74	71.2
6 – 10	16	15.4
11 – 15	10	9.6
16 – 20	4	3.9
21+	0	0
How many acres do you cultivate in a year?		
< 1 acre	50	48.1
1 – 5	40	38.5
6 – 10	8	7.7
11 – 15	4	3.9
16 – 20	2	1.9
> 20	0	0
$\chi^2 = 137.41$,		

In Table 5 also some other personal data of Extension Officers are presented. About academic qualification, 81.8% of the Extension Officers obtained General Certificate in Agriculture followed by Diploma in Agricultural Extension (13.6%), then B.Sc. Extension in Farm Management (4.6%). For experience, 40.9% of them have been providing extension services for 6-10 years whilst 18.2% have been doing it for 16-20 years. The differences between the observed and expected responses were very highly significant ($\chi^2 = 41.46$, P = 0.001). Also, 45.5% of the Extension Officers claimed that they have 1-20 farmers under them whilst 22.7% do not know the number of cowpea farmers under their operational area. Differences between the observed and expected responses were very highly significant ($\chi^2 = 33.46$, P = 0.001)

Concerning which insects do visit the cowpea flowers it is only lepidopterans (butterflies and moths) that registered a mean of 1.5 for the farmers indicating that half of the number of farmers agreed that lepidopterans do visit the flowers. The results showed that all the other insects have been rejected by majority of the farmers as insects that visit the cowpea flowers. However, for the Extension Officers bees registered a mean of 1.86 and lepidopterans registered 1.7. All the other insects registered means less than 1.5 (Table 6)

In responding to what specifically some selected insects do on the cowpea flowers 62 (59.6%) and70 (67.3%) farmers considered bees and lepidopterans respectively as pollinators whilst 66 (63.5%), 48 (46.2%) and 36 (34.6%) of them considered beetles, ants and flies (Dipterans) respectively as pests (Table 7). Also, 40 (90.9%), and 30 (68.2%) Extension Officers considered bees and lepidopterans respectively as pollinators whilst 24 (54.6%) and 30 (68.2%) of them considered thrips and flies respectively as pests. Generally, large numbers of both farmers and Extension Officers did not respond to show whether some of the insects are predators, pollinators or pests. Similarly, both groups scored low figures in considering the insects as predators (Table 7).

Table 5: Personal data of Agricultural Extension Officers (N = 44)

Item / Response		
What is your highest academic/professional qualification?	**Freq.**	**% Freq**
General Certificate in Agriculture	36	81.8
Diploma in Agricultural Extension	6	13.6
B.Sc. Extension in Farm Management	2	4.6
For how long have you been an extension officer (in years)?		
1 – 5	4	9.1
6 – 10	18	40.9
11 – 15	5	11.4
16 – 20	8	18.2
21 – 25	2	4.56
26 – 30	6	13.6
31+	0	0
No response	1	2.3
$\chi^2 = 41.46$		
How many cowpea farmers do you have under your care?		
1 - 20	20	45.5
21 – 40	4	9.1
41 – 60	6	13.6
61 – 80	0	0
81+	4	9.1
Do not know	10	22.7
$\chi^2 = 33.46$		

Table 6: Respondents' perceptions about insects that visit cowpea flowers

Item / Response	Response of farmers and Extension Officers			
	Farmers (N= 102)		Extension Officers (N=44)	
	Mean	SD	Mean	SD
This insect visits the cowpea flowers				
Bees	1.4	0.5	1.9	0.4
Lepidopterans (butterfly and moth)	1.5	0.5	1.7	0.5
Flies	1.4	0.5	1.2	0.4
Ants	1.2	0.4	1.5	0.5
Wasps	1.1	0.3	1.3	0.5
Beetles	1.3	0.5	1.3	0.5
Thrips	1.1	0.3	1.4	0.5

Key: For the means: 1 – 1.4 = majority disagreed; 1.5 = 50% agreed; 1.6 - 2 = majority agreed.

As many as 102 (98.0%) farmers have ever heard of pollinators whilst all the Extension Officers also responded in the positive (Table 8). The results also indicated that 99 (98.1%) of farmers and 39 (88.6%) of Extension Officers who agreed to have ever heard of pollinators said that pollinators transfer pollen grains from the anther to the stigma. It is also interesting to note that 3 (1.9%) of the farmers and 5 (11.4%) of the Extension Officers were of the opinion that pollinators harm or destroy flowers. Hundred farmers (98.0%) and all the Extension Officers stated that insects cause pollination.

Table 7: Responses concerning the role of cowpea insect flower visitors

	Role of insect on flowers							
	Cowpea farmers				Extension Officers			
	Predator	Pollinator	Pest	Do not know	Predator	Pollinator	Pest	Do not know
Insect	% Freq	% Freq	% Freq	% Freq	% Freq	% Freq	% Freq	% Freq
Bees	4.5	59.6	0	35.9	4.6	90.9	0	4.6
Lepidopterans	0	67.3	5.8	26.9	0	68.2	13.6	18.2
Flies	2.0	11.5	34.6	51.9	0	0	68.2	31.8
Ants	0	0	46.2	53.8	36.4	0	18.2	45.4
Wasps	0	1.9	1.9	96.2	13.6	13.6	18.2	54.6
Beetles	0	7.7	63.5	28.8	18.2	0	27.3	54.5
Thrips	0	1.9	21.2	76.9	4.6	0	54.6	40.8

When asked to rate their knowledge about pollinators, 44 (42.3%) of the farmers rated themselves less than 40% whilst 28 (36.5%) of them rated themselves 40-50%. The differences between the observed and expected frequencies were very highly significant (χ^2 = 94.24, P = 0.001) (Table 9). On the part of Extension Officers 16 (36.4%) rated themselves 51 -60%; 13 (31.8%) rated it 40 -50% and 6 people (13.6%) rated it less than 40%. The differences between the observed and expected frequencies were highly significant (χ^2 = 44; P = 0.001).

Table 8: Distribution of respondents in relation to their knowledge of pollinators

	Cowpea Farmers		Extension Officers	
Item / Response	**Freq**	**% Freq**	**Freq**	**% Freq**
Have you ever heard of pollinators?				
Yes	102	98.1	44	100
No	2	1.9	0	0
Total	104		44	
What role do pollinators play on flowers?				
They transfer pollen grains from anther to stigma	99	98.1	39	88.6
They destroy flowers	3	1.9	5	11.4
They feed on flowers	0	0	0	0
They guard flowers against pests	0	0	0	0
Total	102		44	
Do insects also cause pollination?				
Yes	100	98.0	44	100
No	2	2.0	0	0
Total	102		44	

Table 9: Distribution of respondents concerning how they rated their knowledge about pollinators

Item / Response	Cowpea Farmers		Extension Officers	
	Freq	% Freq	Freq	% Freq
How do you rate your knowledge about pollinators?				
Less than 40%	44	42.3	6	13.6
40 – 50%	28	36.5	13	31.8
51 – 60%	10	9.5	16	36.4
61 – 70%	6	5.8	0	0
71 – 80%	6	5.8	8	18.2
81 – 90	6	5.8	0	0
91 - 100	4	3.9	0	0
Total	104		44	
χ^2 =	94.24		41.49	

Concerning the benefits of pollination, increased fruit set/increased crop yield recorded a mean of 1.8 for farmers whilst all the other points scored means less than 1.5. Similarly, increased fruit set/increased crop yield scored a mean of 2.0 and increased fruit viability scored a mean of 1.5 for Extension Officers. Here also all the other points scored means less than 1.5 (Table 10). Talking about farming practices that are harmful to flower visitors/pollinators, pesticide application scored a mean of 1.9 for farmers and 2.0 for Extension Officers. All the rest of the points scored less than 1.5 for both farmers and Extension Officers (Table 10).

Table 10: Respondents' perceptions about some other issues of pollinators

ITEM / RESPONSE	Response of farmers and Extension Officers			
	Farmers (N = 102)		Extension Officers (N=44)	
	Mean	SD	Mean	SD
This is a benefit of pollination				
Increased fruit set / increased crop yield	1.8	0.4	2.0	0.2
Increased seed viability	1.5	0.5	1.5	0.5
Faster growth of plants	1.1	0.3	1.2	0.4
Reduction in fruit drop	1.1	0.2	1.1	0.4
Enhanced resistance to diseases	1.0	0.2	1.2	0.4
Increase in oil content in oil seed crops	1.0	0	1.0	0
Increase in the number and size of seeds	1.1	0.3	1.2	0.4
Formation of more nutritive and aromatic fruits	1.0	0.1	1.0	0
This is a farming practice that causes harm to flower visitors / pollinators				
Pesticide application	1.9	0.3	2.0	0.4
Weeding the undergrowth of the crops	1.1	0.3	1.2	0.4
Mixed cropping	1.1	0.2	1.1	0.2
Harvesting	1.0	0	1.0	0

Key: For the means: 1-1.4 = majority disagreed; 1.5 = 50% agreed; 1.6 - 2 = majority agreed.

All the Extension Officers and 100 (96.2%) farmers agreed that farmers need some training in the knowledge of pollinators and their usefulness (Fig 3).

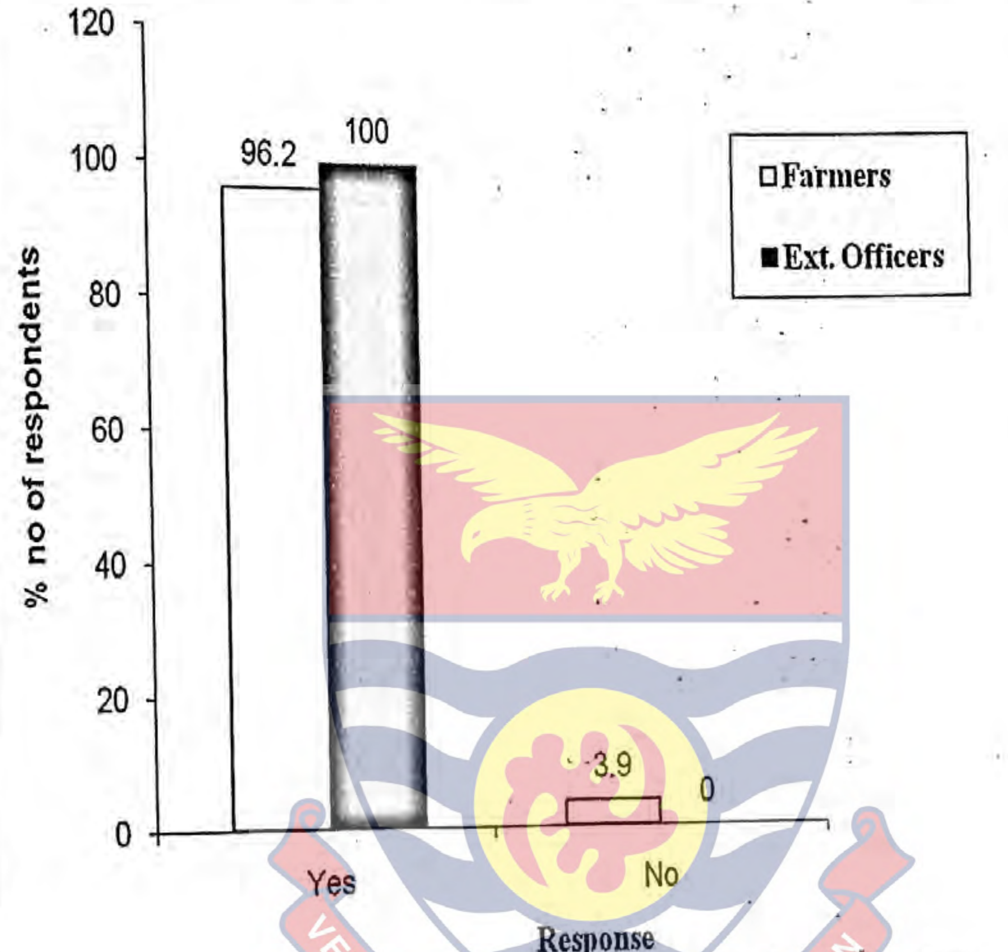


Fig. 3: Responses to whether farmers should be given training in the knowledge of pollinators and their usefulness

On whether the training is done for the farmers 86.4% of the Extension Officers responded in the affirmative while 13.6% responded in the negative (Fig. 4).

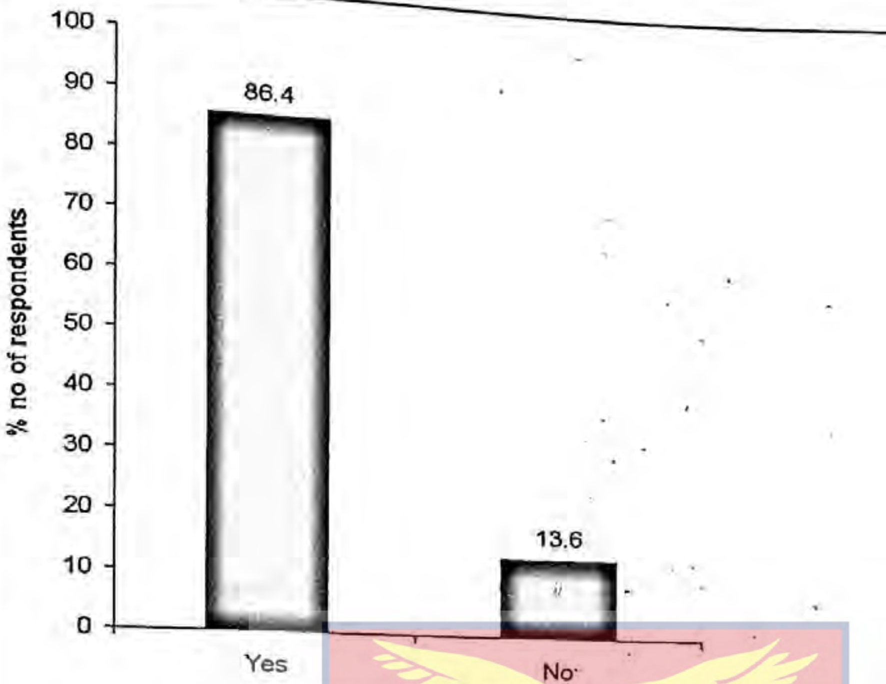


Fig. 4: Responses of Extension Officers on whether the training in the knowledge of pollinators and their usefulness is done for the farmers

Concerning reasons why cowpea farmers should be given training in the knowledge of pollinators and their usefulness, Agricultural Extension Officers indicated that it:

- will enable the farmers to know the importance of pollinators so that they will not destroy them through any pest control means,
- is because the farmers do not know the difference between pests and pollinators,
- will help the farmers to know how to identify pollinators and other useful insects, and
- is because the farmers do not know much about pollinators and their usefulness

The Extension Officers who agreed that they take the farmers through training on the importance of pollinators stated the following topics as those that they take the farmers through:

- insect pest control measures,
- types of pollination agents,
- the right time to spray chemicals,
- the right dose of chemicals to spray, and
- the need to carry beehives to farms during flowering.

The reasons given by the officers who indicated that they are not able to do the training for the farmers though they saw the need for it are that:

- they, the officers themselves have limited knowledge about pollinators and pollination.
- it is because they, the officers have limited time.

In response to what is done when pests infest the crops, 94 (90.4%) of farmers and 36 (81.8 %) of extension officers asserted that the crops are sprayed with chemicals (Fig. 5). Out of the 94 farmers who agreed on chemical applications 47 (50.0%) and 31 (33.0%) stated that chemicals are sprayed twice and once respectively during a cropping period. On the part of Extension Officers 19 (52.8%) and 11 (30.6%) indicated that chemicals are sprayed once and twice respectively (Table 11). About the effects of chemicals on insect pollinators, as many as 60 (57.7%) farmers indicated that they did not know whilst 32 (30.8%) claimed that the pesticides kill pollinators, 12 (11.5%) indicated that pesticides do not have any effects on pollinators. However, all the Extension Officers agreed that pesticides can kill insect pollinators (Table 11). On the issue of whether other insects apart from pests are killed by the chemicals, 52 (55.3%) of farmers agreed whilst 42 (44.7%) indicated that only the pests are killed. However, all the Extension Officers indicated that only the pests are killed (Table 11).

Concerning the flower visitors, apart from pests that are killed by pesticide application, farmers agreed on ants, beetles and flies whilst Extension Officers generally agreed on all the insects except wasps (Table 12). Whilst cowpea farmers agreed that the cowpea plants are sprayed at the beginning of flowering, Extension Officers agreed on before flowering and at fruiting stages (Table 12).

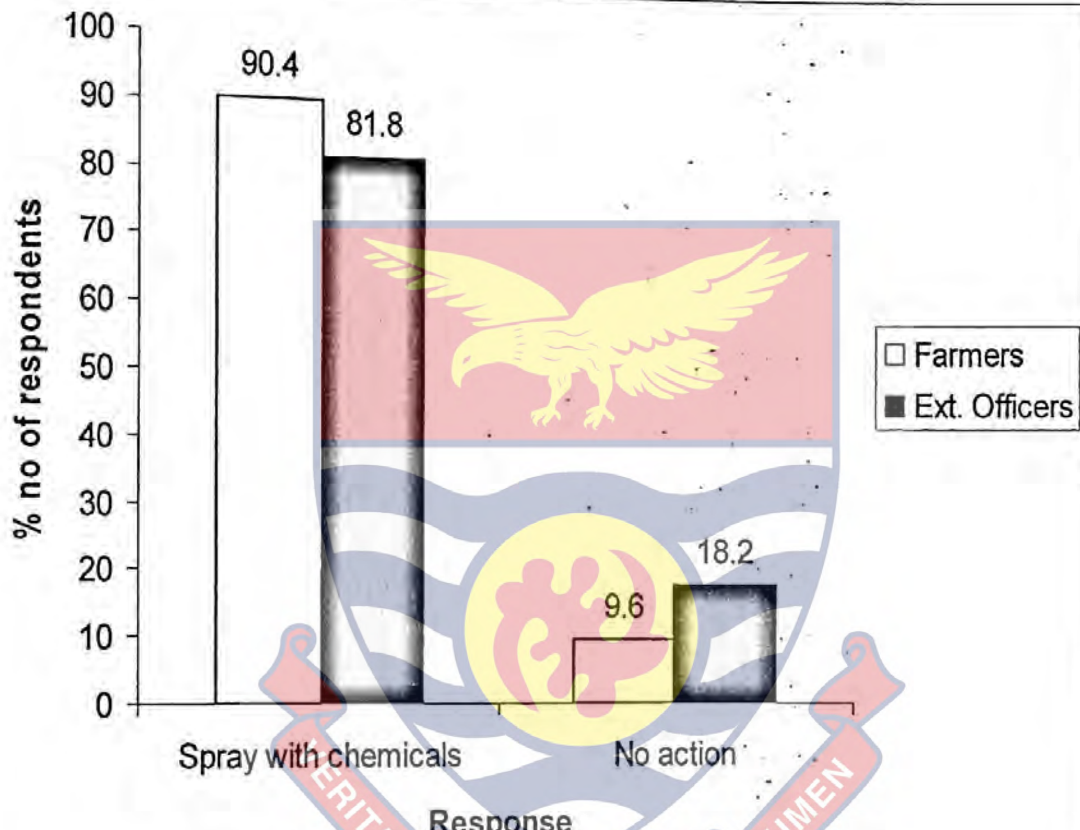


Fig. 5: Views of respondents on what is done when pests infest cowpea plants

Table 11: Distribution of respondents concerning chemical application and its effects on insects in cowpea farms

Item / Response	Cowpea farmers		Extension officers	
	Freq	% freq.	Freq	% freq.
How often are chemicals sprayed before the crops are harvested?				
Once	31	33.0	19	52.8
Twice	47	50.0	11	30.6
Three times	8	8.5	4	11.1
Four times	6	6.4	2	5.6
Five times	2	2.1	0	0
Total	94		36	
What are the effects of chemicals on insect pollinators?				
Chemicals kill insect pollinators	32	30.8	44	100
Chemicals make insect pollinators to breed more	0	0	0	0
No effects	12	11.5	0	0
Do not know	60	57.7	0	0
Total	104		44	
After chemical application are other insects apart from pests killed?				
Only pests are killed	42	44.7	36	100
Other insects are also killed	52	55.3	0	0
Total	94		36	

Table 12: Respondents' perceptions about some other issues of chemical spraying in cowpea farms

Item / Response	Response of farmers and Officers			
	Farmers (N=104)		Extension Officers (N=44)	
	Mean	SD	Mean	SD
This is one of the other flower visitors killed after spraying chemicals				
Bees	1.2	0.4	1.6	0.5
Lepidopterans	1.4	0.5	1.7	0.5
Wasps	1.0	0	1.4	0.5
Beetles	1.6	0.5	1.5	0.5
Flies	1.6	0.5	1.6	0.5
Ants	1.8	0.4	1.6	0.5
This is the stage of plants at which spraying is done				
Before flowering	1.4	0.5	1.7	0.5
At the initiation of flowering	1.6	0.5	1.3	0.5
At fruiting stage	1.1	0.3	1.6	0.5
Throughout cropping period	1.0	0.2	1.1	0.3
Any time pests emerge	1.1	0.3	1.1	0.4

Key: For the means: 1 – 1.4 = majority disagreed; 1.5 = 50% agreed; 1.6 - 2 = majority agreed.

Apart from chemical control, farmers could not generally agree on any other pest control measures that were available to them. The Agricultural Extension Officers also agreed that none of the methods presented to them was available to the farmers (Table 13). In all, 56 (53.9 %) farmers agreed that Agricultural Officers advise them (farmers) on chemical control whilst 48 (46.2%) disagreed. . Meanwhile, all the Extension Officers agreed that the farmers are advised by Agricultural Officers on chemical applications (Fig. 6)

Table 13: Respondents' perception of other pest control measures available to cowpea farmers

Item / Response	Response of farmers and extension officers			
	Farmers (N = 104)		Extension officers (N=44)	
	Mean	**SD**	**Mean**	**SD**
This is a pest control measure available to farmers other than chemical application				
Biological control	1.2	0.4	1.3	0.5
Use of pest resistance crop varieties	1.2	0.4	1.4	0.5
Use of cultural practices	1.4	0.5	1.4	0.5
None above	1.3	0.5	1.1	0.2

Key: For the means: 1 – 1.4 = majority disagreed; 1.5 = 50% agreed; 1.6 - 2 = majority agreed.

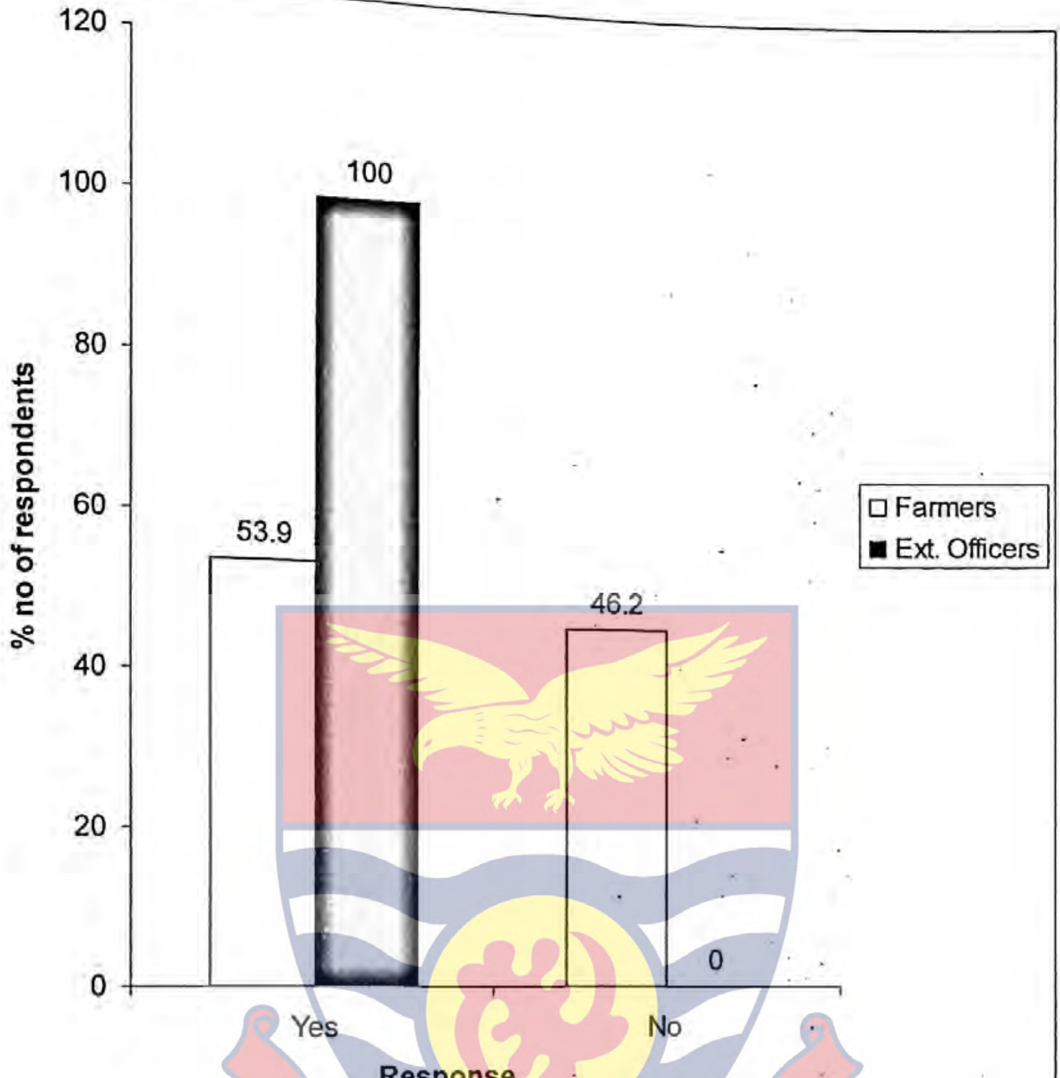


Fig. 6: Views of respondents on whether Agricultural Extension Officers advise farmers on chemical application

Farmers who indicated that Agricultural Officers advise them on chemical control measures could not generally agree on any specific topic on which the training is centered whilst all the Extension Officers agreed on all the topics (Table 14)

Table 14: Respondents' perceptions concerning types of topics on which cowpea farmers are advised concerning chemical application

Item / Response	Response of farmers and Extension Officers			
	Farmers (N = 104)		Extension Officers (N=44)	
	Mean	**SD**	**Mean**	**SD**
Yes farmers are advised on chemical application on the topic:				
Types of chemicals to apply for a particular pest	1.4	0.5	1.9	0.3
Concentration of chemicals to be applied	1.3	0.4	2.0	0.2
Number of times to spray chemicals before harvesting	1.3	0.5	1.9	0.3
Time of the day for application	1.3	0.5	1.9	0.3
Growth stage of the plants when chemical application can be done	1.3	0.4	1.7	0.5
Pest population demanding chemical application	1.1	0.3	1.5	0.5

Key: For the means: 1 – 1.4 = majority disagreed; 1.5 = 50% agreed;1.6 - 2 = majority agreed.

Karate, Actellic, Pawa and Cymbush were the most popular chemicals stated by the farmers as those that they use in the cowpea farms, whilst the most popular with the extension officers were Karate, Dursban, Cymbus and Actellic (Table 15).

Table 15: Chemicals that respondents considered as those commonly sprayed (In descending order of popularity)

Cowpea farmers			Extension officers		
Trade name	Active ingredients	Used as	Trade name	Active ingredients	Used as
Karate***	Lambda cyhalothrin	Field insecticide	Karate***	Lambdacyhalothrin	Field insecticide
Actellic***	Pirimiphos- methyl permethrin	Storage pesticide	Dursban***	Chrorphrifos	Field insecticide
Pawa***,	Lambda cyhalothrin	Field insecticide	Cymbush***	Cypermethrin	Field insecticide
Cymbush***	Cypermethrin	Field Insecticide	Actellic	Pirimiphos methyl permethrin	Storage pesticide
Delsis** (Decis)	Deltamethrin	Field Insecticide	Pawa**,	Lambda cyhalothrin	Field insecticide
Dithane**,	Mancozeb	Fungicide	Polytrine**,	None	None
Wreko 25**,	None	A company	Dimethoate super** (Dimethoate)	Dimethoate	Field Insecticide
Dursban**	Chrorphrifos	Field insecticide	Thiodan**	Endosulfan	Field insecticide
Gammalin20*	Lindane	Banned pesticide	Sumicumbi*,		
DDT*	Dichlorodiphenyltrichloro-ethane	Banned pesticide	Fungicide/Dopson/ Dithane*	Mancozeb	Fungicide
Smithrin*,					
Cypercal*	Cypermethrin	Field insecticide	-	-	-
Wood ash*,	None	None	-	-	-

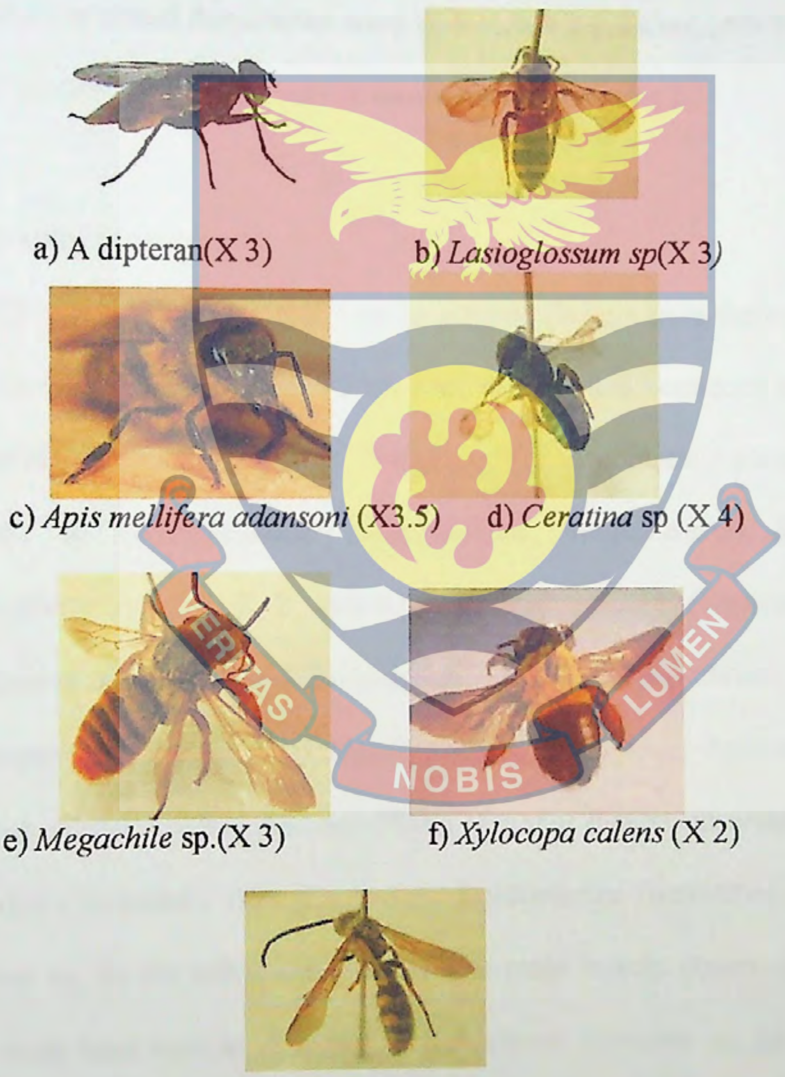
Table 15 contd.

Ambush*,			-	-	-
Round up*,	Glyphophate	Herbicide	-	-	-
Kocide*,	Copper hydroxide	Fungicide	-	-	-
Harvestmore*,	NPK30-10-10	Floral fertilizer	-	-	-
Champion*,	Cyhalon-cyhalonthin	Fungicide	-	-	-
Pothene*,	None	None	-	-	-
Sharp*	None	None	-	-	-

Key: * = popular
** = more popular
*** = most popular;
- = no pesticide stated
None = not known

Field survey of farms

Throughout the survey, the insects observed on the cowpea flowers were flies (Dipterans), wasps (Hymenoptera); bees such as *Lasioglossum* sp (Hymenoptera: Halicitidae; Halicitinae), *Apis mellifera adansoni* (Hymenoptera: Apidae), *Ceratina sp* (Hymenoptera: Apidae; Xylocopinae), *Megachile* sp. (Hymenoptera: Megachilidae; Megachilinae), and *Xylocopa calens* (Hymenoptera: Apidae; Xylocopinae) (Plate 13). Other insects collected were thrips, lepidopterans and ants.



a) A dipteran(X 3) b) *Lasioglossum sp*(X 3)

c) *Apis mellifera adansoni* (X3.5) d) *Ceratina* sp (X 4)

e) *Megachile* sp.(X 3) f) *Xylocopa calens* (X 2)

g) A wasp (X3)

Plate 13: Insects collected on cowpea flowers during survey

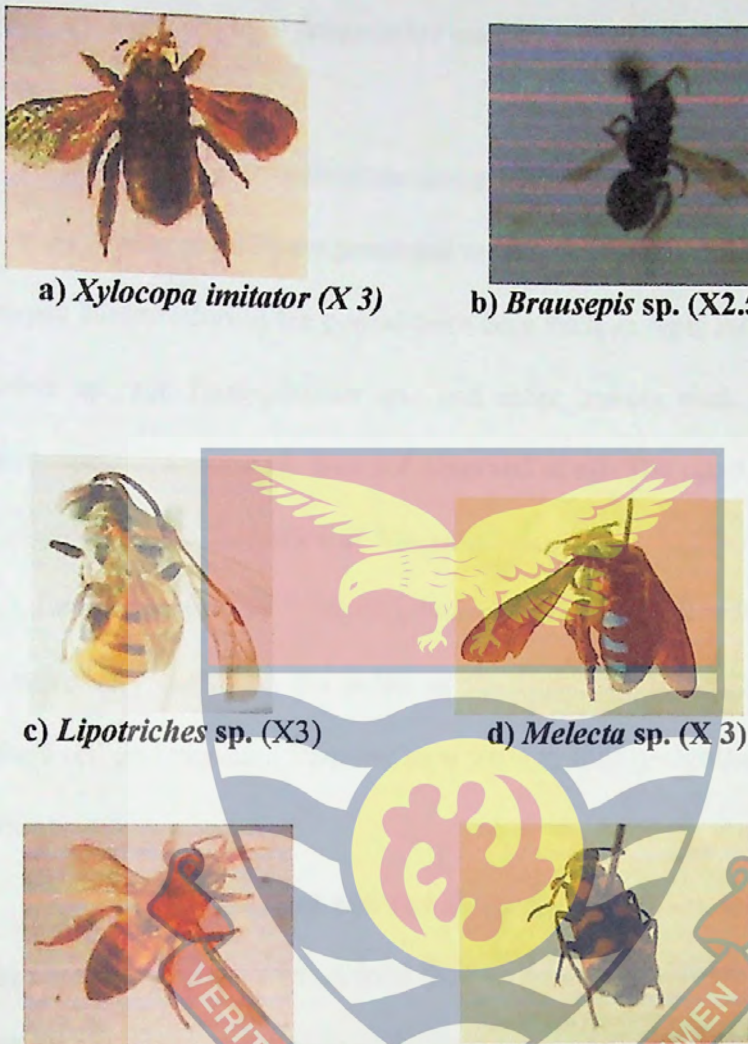
Thrips were the insects most often observed on the cowpea flowers in the surveyed farms (total number of 490 [44.8%]), followed by flies (Dipterans) (total number of 243 [22.2%]), lepidopterans (total number of 99 [9.0%]), and *Lasioglossum* sp (Halicitidae: Halicitinae) (total number of 92 [8.4%]). Thrips recorded 17.4% on the tip of stigma and 16.3% on petals while flies recorded 11.9% on the tip of stigma and 10.3% on petals. *Lasioglossum* sp. also recorded 6.4% on the tip of stigma and 2.0% on the petals. The differences between the observed and expected frequencies of the total computed frequencies were very highly significant (df= 9; χ^2 = 1879.12; P = 0.005) (Table 16). The full survey results are in Appendix 2.

Experimental farm results

The main insects observed on the cowpea flowers from the experimental farm during the major rainy season in 2006 were beetles, and bees such as Apis *mellifera adansoni* (Hymenoptera: Apidae), *Ceratina sp* (Hymenoptera: Apidae; Xylocopinae), *Megachile* sp. (Hymenoptera: Megachilidae; Megachilinae), *Xylocopa calens* (Hymenoptera: Apidae; Xylocopinae), *Xylocopa imitator* (Hymenoptera: Apidae; Xylocopinae), *Brausepis sp*.(Hymenoptera: Halictidae; Halictinae), *Lipotriches* sp. (Hymenoptera: Halictidae; Halictinae), *Melecta* sp (Apidae; Apinae), and *Amegilla* sp.(Hymenoptera: Apidae; Apinae) (Plate14). Other insects observed on the flowers were thrips (Thripidae), flies (Dipterans), lepidopterans (butterflies and moths), and *Dysdercus* sp. In the minor rainy season the main insects observed on the cowpea flowers were bees such as *Apis mellifera adansoni, Ceratina* sp, *Megachile* sp., and *Lasioglossum* sp.; and other insects such as thrips, flies and lepidopterans.

Table 16: The percentage frequency of insects on flowers from 13 surveyed farms

Type of insect	No of farms (plots)	Position on the flower						TOTAL	
		On petal		On tip of stigma		Inside flower			
		Freq.	% freq	Freq.	% freq.	Freq.	% freq.	Freq.	% freq.
Apis mellifera adansoni	7	11	1.0	45	4.1	0	0	56	5.1
Ceratina Sp	4	6	0.6	24	2.2	4	0.4	34	3.1
Thrips	12	178	16.3	191	17.4	121	11.1	490	44.8
Crickets	1	2	0.2	0	0	0	0	2	0.2
Flies	11	113	10.3	130	11.9	0	0	243	22.2
Butterfly / moth	12	60	5.5	39	3.6	0	0	99	9.0
Megachile sp.	2	7	0.6	22	2.0	0	0	29	2.7
Lasioglossum sp	9	22	2.0	70	6.4	0	0	92	8.4
Ants	2	10	0.9	7	0.6	21	1.9	38	3.5
Wasps	1	2	0.2	0	0	0	0	2	0.2
Beetles	1	2	0.2	3	0.3	0	0	5	0.5
Xylocopa sp.	1	2	0.2	3	0.3	0	0	5	0.5
Total		415	37.9	534	48.7	146	13.3	df=9; χ^2=1879.12	



a) *Xylocopa imitator (X 3)* b) ***Brausepis*** **sp. (X2.5)**

c) ***Lipotriches*** **sp.** (X3) d) ***Melecta*** **sp. (X 3)**

e) ***Amegilla*** **sp.** (X3) f) A beetle (X 3)

Plate 14: Insects collected on the cowpea flowers from the experimental farm

In the major rainy season, the insect most observed on flowers was thrips (525 = 27.3%) followed by beetles (519 = 27.0%), *Xylocopa calens* (258 = 13.4%), *Ceratina* sp. (175 = 9.1%), Lepidopterans (119 = 6.2%), flies (111 = 5.8%) and *Xylocopa imitator* (107 = 5.6%) (Table17). Though most often observed on the petals, thrips and beetles were also observed quite a number of times on the stigma and inside of the flowers. *Xylocopa calens* and *Ceratina* sp. were most often observed on the tip of the stigma. *Ceratina* was most often observed excavating the flowers and appeared to be feeding on the pollen grains. The differences between the observed and expected total frequencies were very highly significant ($\chi^2 = 3051.15$; P = 0.001).

Results of insects observed on flowers from the experimental farm during the minor rainy season in 2006 are presented on table 18. The main insects observed on the cowpea flowers during the period were bees such as Apis *mellifera, Ceratina* sp. *Megachile* sp. and *Lasioglossum* sp.; and other insects such as thrips, flies and Lepidopterans. *Xylocopa* sp. was not observed at all. The most active insect on the tip of stigmas of the flowers was *Megachile* sp. (79 = 36.2%) whilst thrips (43 = 19.7%), Lepidopterans (31 = 14.2%), *Lasioglossum* sp. (20 = 9.2%) and flies (19= 8.7%) were very active on the petals of the flowers. The differences between the total observed and expected frequencies were very highly significant ($\chi^2 = 154.61$; P = 0.001)

The results of fruit set and pod development for the major rainy season of 2006 are presented in table 19. A total fruit set of 284 (61.7%) and fruit set failure of 176 (38.3%) were recorded. Out of the total successful fruit set, 20.1%, 19.37% and 19.4% were recorded for flowers not exposed to organisms (control), flowers visited by *X. calens* and thrips respectively. The differences between the total observed and expected frequencies for the successful fruit set were very highly significant ($\chi^2 = 155.32$; P = 0.001)). Out of the 284 successful fruits set, 125 (44.0%) developed into pods whilst 159 (56.0%) aborted.

Table 17`: Number of times each insect visitor was observed on cowpea flowers in the experimental farm during the major rainy season, 2006

Type of insect visitor	Number of times each type of insect was observed on various parts of the flower							
	On petals		On the tip of stigma		Inside flower		TOTAL	
	Freq	% freq	Freq	% freq	Freq	% freq	Freq	% Freq
Apis mellifera	0	0	26	1.4	0	0	26	1.4
Xylocopa calens	59	3.1	189	9.8	10	0.5	258	13.0
Xylocopa imitator	32	1.7	75	3.9	0	0	107	5.6
Ceratina sp	44	2.3	110	5.7	21	1.1	175	9.1
Brausepis sp	0	0	4	0.2	0	0	4	0.2
Megachile sp	3	0.2	5	0.3	0	0	8	0.4
Lipotriches sp	1	0.1	0	0	0	0	1	0.1
Melecta sp	5	0.3	7	0.4	0	0	12	0.6
Amegilla sp	0	0	4	0.2	0	0	4	0.2
Thrips	189	9.8	215	11.2	121	6.3	525	27.3
Flies	58	3.0	53	2.6	0	0	111	5.8

Table 17 contd.

Lepidopterans	68	3.5	44	2.3	7	0.4	119	6.2
Beetle(spotted beetle)	169	8.8	242	12.6	108	5.6	519	27.0
Dysdercus sp	30	1.6	18	0.9	8	0.4	56	2.9
Total	658		992		275		1925	

$\chi^2 = 3051.15$

In all, 28.0% and 25.0% pods development were recorded for flowers visited by *X. calens* and unexposed flowers (control) respectively. The differences between the total observed and expected frequencies for the successful pod development were very highly significant (χ^2=136.32; P = 0.001). Fruit abortion rate was highest for flowers visited by thrips (14.1%), followed by control flowers (8.8%), flowers visited by *X. calens* (7.0%), *Apis mellifera* and *X. imitator* (5.3% each) (Table 19). Results on table 20 indicate that flowers visited by *Megachile* sp. recorded higher fruit set (36.7%) and higher pod development (46.1%) than the flowers not exposed to organisms (control) (26.7% and 32.9% respectively). Chi square analysis showed a very significant relationship between the expected and observed frequencies for both fruit formation (χ^2 = 24.0; P = and pod formation (χ^2 = 38.28; P = 0.001).

Table 18: Number of times each insect visitor was observed on cowpea flowers in the experimental farm during the minor rainy season, 2006

Type of visitor	Number of times each type of insect was observed on various parts of the flower			Total	
	On petals	On the tip of stigma	Inside flower		
	% Freq.	% Freq.	% Freq.	Freq.	% Freq.
Apis mellifera	1.38	0	0	3	1.4
Megachile sp.	0	36.2	0	79	36.2
Ceratina sp.	0	2.3	0	5	2.3
Lasioglossum sp.	9.2	0	0	20	9.2
Flies	8.7	0	0	19	8.7
Lepidopterans	14.2	0	0	31	14.2
Thrips	19.7	3.67	4.6	61	28.0
Total	116	92	10	218	
				χ^2 = 154.61	

Table 19: Fruit set and pod development in the experimental farm during the major rainy season, 2006

	Fruit formation					Pod development			
	Success		Failure		Total no of flowers	Success		Failure	
Type	Freq	% Freq	Freq	% Freq		Freq	% Freq	Freq	% Freq
Control(Unexposed flowers)	57	20.1	22	12.5	79	32	25.6	25	8.8
Apis mellifera	15	5.3	6	3.4	21	0	0	15	5.3
Xylocopa calens	55	19.4	24	13.6	79	35	28.0	20	7.0
Xylocopa imitator	22	7.8	26	14.8	48	7	5.6	15	5.3
Ceratina sp.	21	7.4	6	3.4	27	18	14.4	3	1.1
Megachile sp.	3	1.1	1	0.6	4	0	0	3	1.1
Melecta sp	3	1.1	0	0	3	0	0	3	1.1
Thrips	55	19.4	15	8.5	70	15	12.0	40	14.1
Flies	18	6.3	5	2.8	23	5	4.0	13	4.6
Lepidopterans	18	6.3	8	4.6	26	9	7.2	9	3.2
Beetle (spotted)	17	6.0	63	35.8	80	4	3.2	13	4.6
Total	284	61.7	176	38.3	460	125	44.0	159	56.0
	$\chi^2 = 155.32$					$\chi^2 = 136.32$			

Table 20: Fruit set and pod development in the experimental farm during the minor rainy season, 2006

Type	Fruit formation				Pod development			
	Success		Failure		Success		Failure	
	Freq	% Freq	Freq	% freq	Freq	% freq	Freq	% Freq
Unexposed flowers	32	26.7	28	23.3	25	32.9	7	9.2
Flowers exposed to *Megachile* sp.	44	36.7	16	13.3	35	46.1	9	11.8
	χ^2 = 24.0; df = 1				χ^2 = 38.28; df = 1			

During the major rainy season, there was no clear cut relationship between fruit formation and any of the weather conditions (rainfall, temperature and relative humidity) (Figs 7-9). During the minor rainy season it appeared that as rainfall increased fruit formation for control or unexposed flowers also increased (Fig. 10). Similarly, as temperature increased there was a corresponding decrease in the number of fruits formed for the control or unexposed flowers (Fig. 11). However, there was no clear cut relationship between fruit formation and relative humidity (Fig.12).

During the major rainy season, majority of the pods developed became mouldy, withered and later fell off. As a result, not all the 125 pods could be checked for number of seeds. For the same reason, seeds in most of the pods were malformed. Hence, seed length and seed circumference were not determined. However, number of seeds per pod was estimated from 80 pods. Out of the 80 pods, 26 (32.5%) developed from flowers visited by *X. calens*, 22 (27.5%) from unexposed flowers (control) and 13 (16.3%) from flowers visited by *Ceratina* sp. In all, 13 (16.3%) and 10 (12.3%) pods that developed from flowers visited by *X. calens* had

7-9 and 10-12 seeds per pod respectively. For the unexposed flowers also, 13 (16.3%) pods had between 4 – 6 seeds per pod (Table 21).

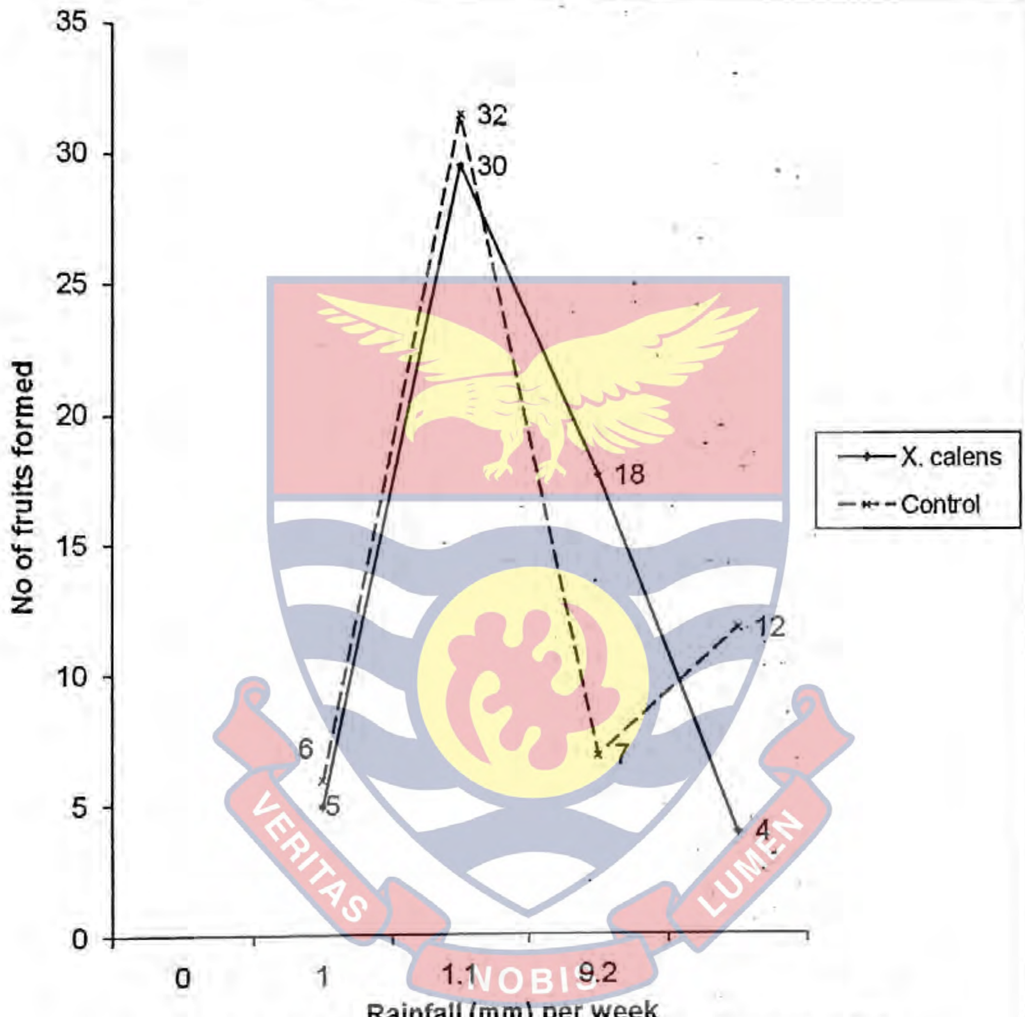


Fig. 7: Relationship between rainfall and fruit formation for flowers visited by *X. calens* and the control flowers during the major rainy season, 2006

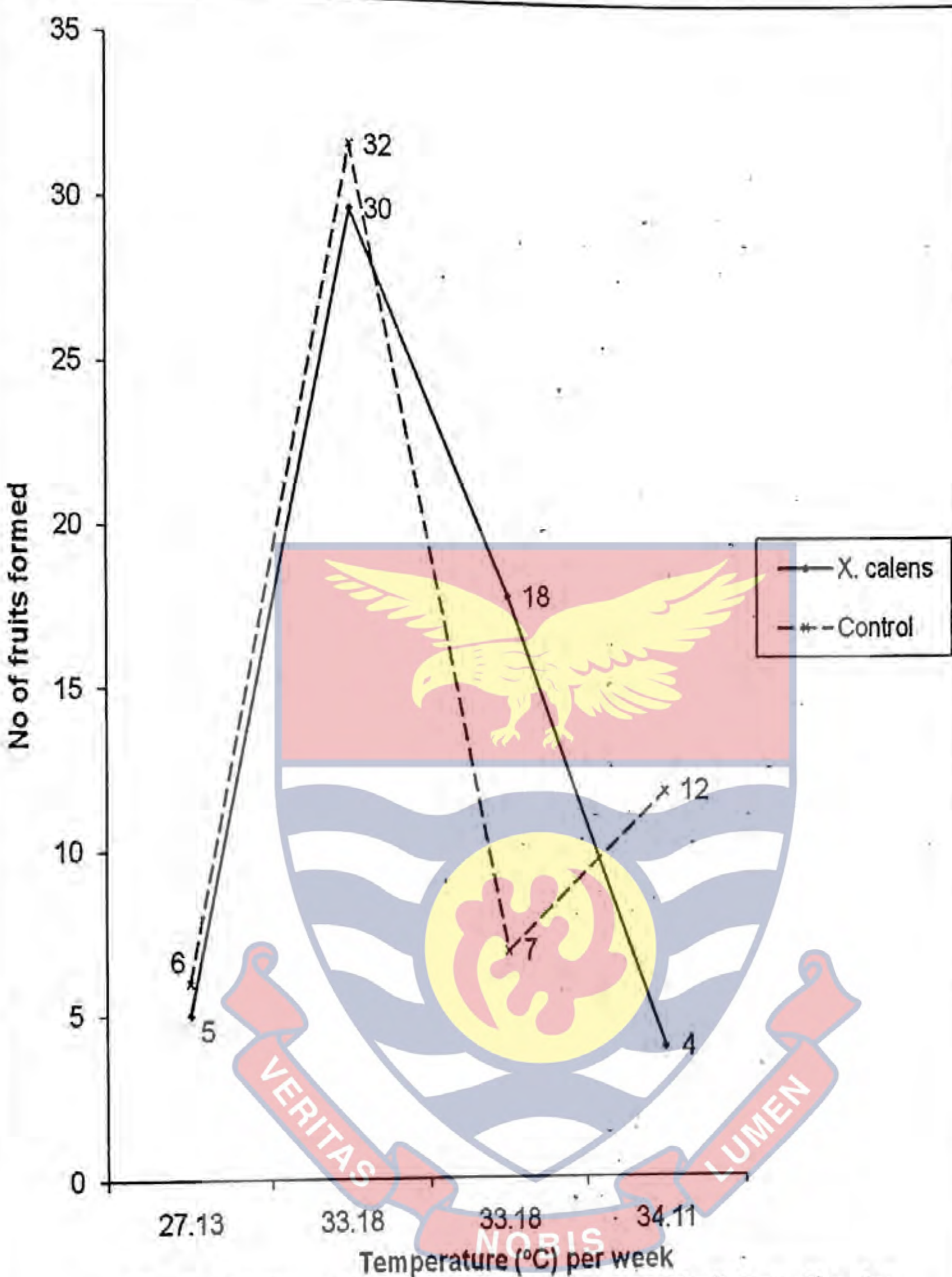


Fig. 8: Relationship between temperature and fruit formation for flowers visited by *X. calens* and control flowers during the major rainy season, 2006

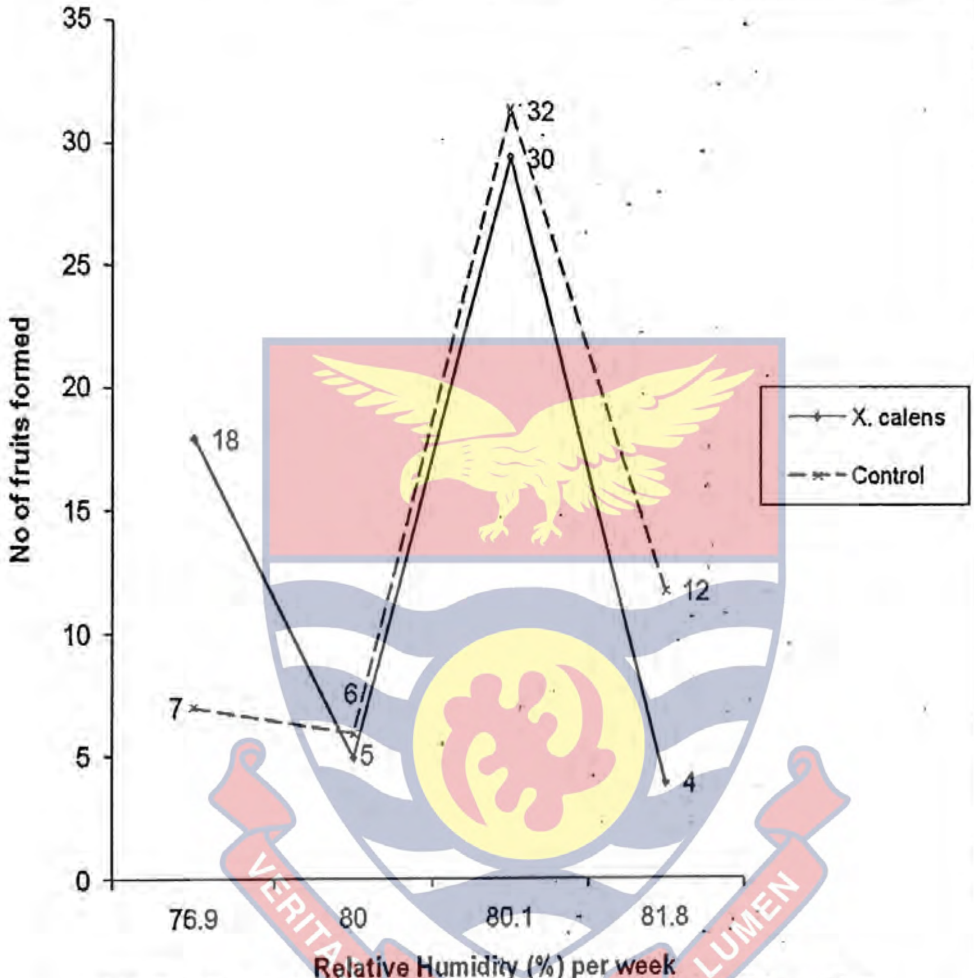


Fig. 9: Relationship between Relative Humidity and fruit formation for flowers visited by *X. calens* and control during the major rainy season, 2006

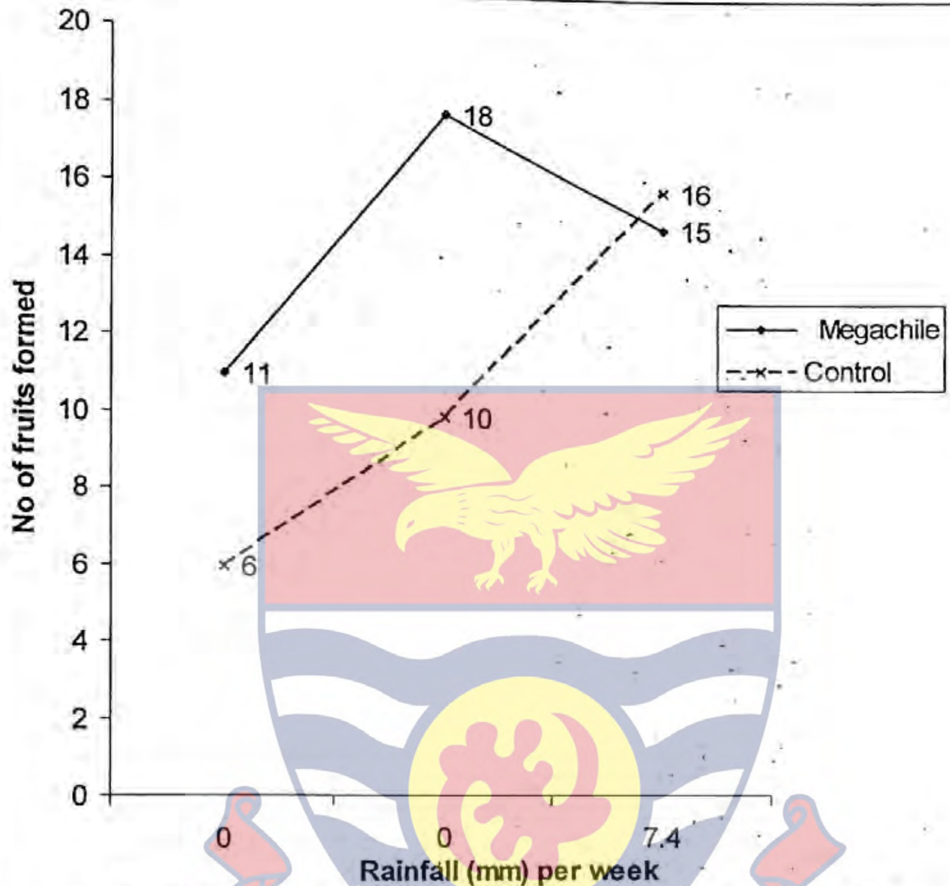


Fig. 10: Relationship between rainfall and fruit formation for flowers visited by *Megachile* sp. and the control flowers during the minor rainy season, 2006

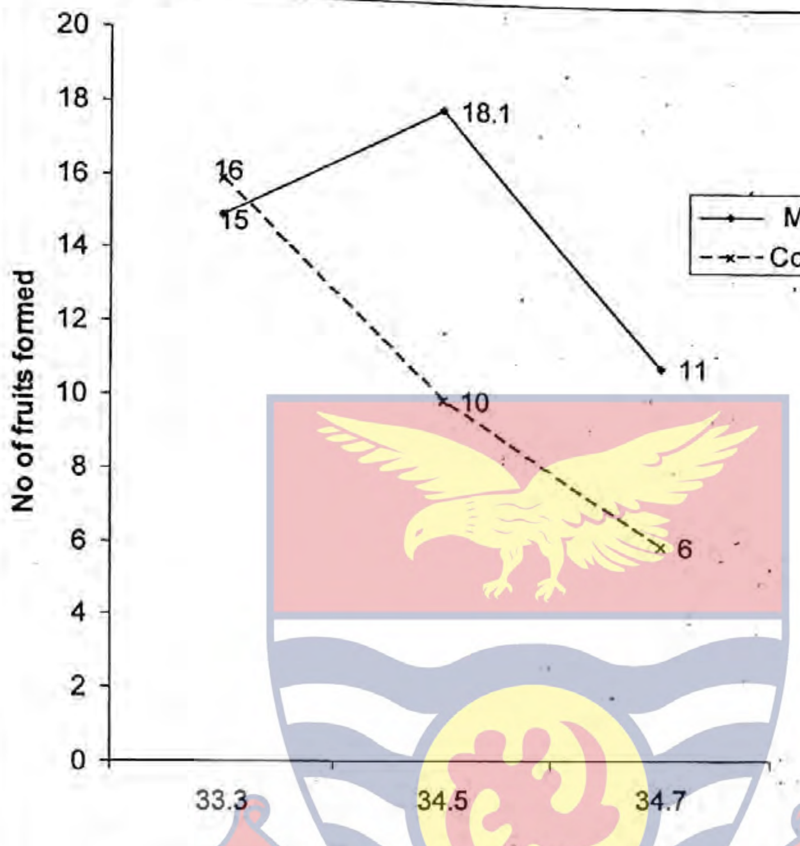


Fig. 11: Relationship between temperature and fruit formation for flowers visited by *Megachile* sp. and control during the minor rainy season, 2006

During the minor rainy season of 2006, the total number of seeds formed in pods developed from flowers visited by *Megachile* sp. (224) was more than that for the unexposed flowers (170) (Table 22). For flowers visited by *Megachile* sp., 20% and 18% of the pods developed 10 - 12 and 7 – 9 seeds per pod respectively. On the other hand for the unexposed flowers, 14% and 20% of pods developed 7 –9 and 4 – 6 seeds per pod respectively. The differences between the observed and expected figures for the number of seeds per pod were not significant ($\chi^2 = 6.42$; P= 0.05).

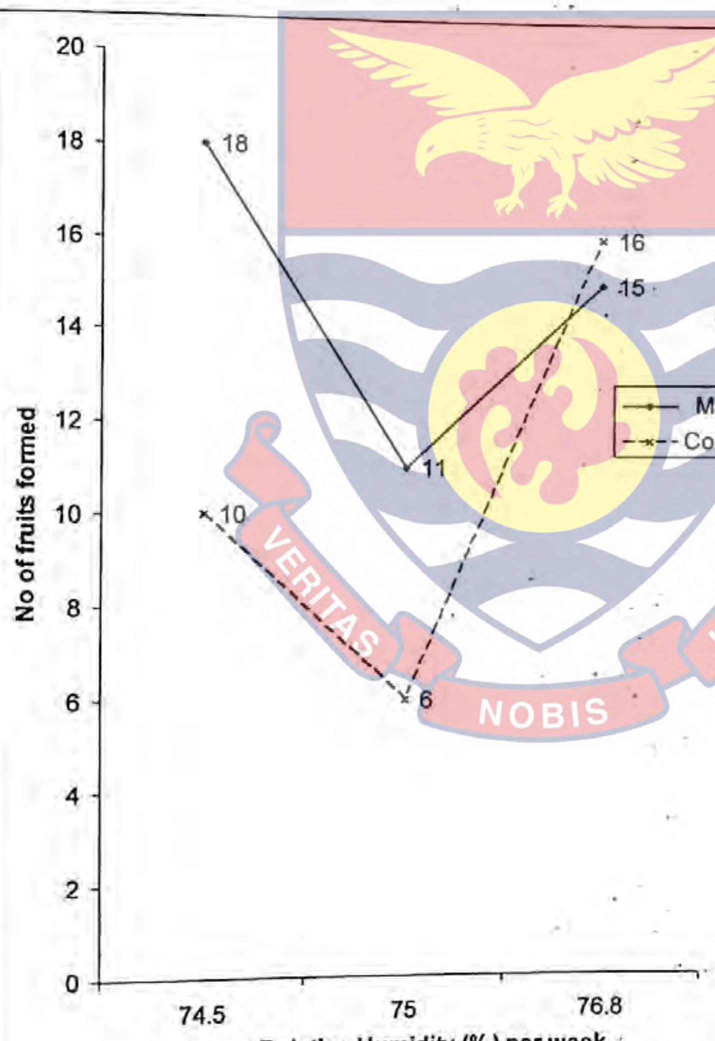


Fig. 12: Relationship between Relative Humidity and fruit formation for flowers visited by *Megachile* sp. and control flowers during the minor rainy season, 2006

Table 21: Number of pods in relation to number of seeds per pod from the experimental farm in the major rainy season, 2006. Percentages in parenthesis

Number of seeds per pod	Number of pods developed from flowers visited by insects and control flowers (N =80)						
	Unexposed Flowers (Control)	*X. calens*	*X. imitator*	*Ceratina* sp.	Diptera	Lepidoptera	Beetle
1-3	4 (5.0)	0	0	2 (2.5)	2 (2.5)	2 (2.5)	1 (1.3)
4 – 6	13 (16.25)	3 (3.8)	1 (1.3)	2 (2.5)	1 (1.3)	7 (8.8)	2 (2.5)
7 – 9	4 (5.0)	13 (16.3)	0	9 (11.3)	2 (2.5)	0	1 (1.3)
10 -12	1 (1.25)	10 (12.3)	0	0	0	0	0

Table 22: Number of pods in relation to number of seeds per pod from the experimental farm in the minor rainy season, 2006. Percentages in parenthesis

Number of seeds per pod	Number of pods developed from flowers visited by *Megachile* sp. and control flowers		
	Control (Unexposed flowers)	Flowers visited by *Megachile* sp.	Total
1 -3	3 (6)	1 (2)	4
4 – 6	10 (20)	4 (8)	14
7 – 9	7 (14)	9 (18)	16
10 – 12	4 (8)	10 (20	14
13+	1 (2)	1 (2)	2
Total	25	25	50
$\chi^2 = 6.42$; df = 5			

Also during the minor rainy season, 198 (50.3%) and 130 (33.0%) of the seeds were of length 0.9 - 1.1cm for flowers visited by *Megachile* sp. and the unexposed flowers respectively. The differences between the observed and expected figures for the seed length were very highly significant (χ^2=16.95; P = 0.01). Also, 161 (40.9%) and 103 (26.1%) of seeds were of circumference 1.6 – 2.0cm for flowers visited by *Megachile* sp. and unexposed flowers respectively (Table 23). The differences between the observed and expected figures for the seed circumference were not significant (χ^2=5.96; P = 0.05).

Table 23: Number of seeds per seed length, and number of seeds per seed circumference from the experimental farm during the minor rainy season, 2006

Seed length (cm)	Unexposed flowers (Control)		Flowers visited by *Megachile* sp.		Seed circumference (cm)	Unexposed flowers (Control)		Flowers visited by *Megachile* sp	
	Freq	% freq	Freq	% freq		Freq	% freq	Freq	% freq
0.6 – 0.8	19	4.8	21	5.3	**1 – 1.5**	10	2.5	12	3.1
0.9 – 1.1	130	33.0	198	50.3	**1.6 – 2.0**	103	26.14	161	40.9
1.2+	21	5.38	5	1.3	**2.1 – 2.5**	57	14.5	51	12.9
Total	170		224			170		224	

Results of experiment with seeds from experimental farm during the minor rainy season – morphological studies of progenies

The results showed that generally, the progenies of flowers visited by *Megachile* sp. developed more flowers than progenies of unexposed flowers (Table 24). In all cases the highest mean number of flowers for the progenies of unexposed flowers (234.0) and flowers visited by *Megachile* sp. (311.5) were recorded during the fourth week of sampling. This was followed by the fifth week of sampling (Table 24). The differences between the means for progenies of flowers visited by *Megachile* sp and progenies of unexposed flowers were highly significant ($t = 3.60$; $df = 7$; $P = 0.01$). The total mean value for the progenies of control was 789.7 and that of the progenies of flowers visited by *Megachile* sp was 1061.8.

Table 24: Mean number of flowers per week for the progenies of control and flowers visited by *Megachile* sp

Week	Mean number of flowers for each type of progeny		Deviation ($X_2 - X_1$) D	Deviation squared (D^2)
	Control (unexposed) flowers (X_1)	flowers visited by *Megachile* sp (X_2)		
1	18.0	31.8	+13.8	191.3
2	36.8	80.0	+43.2	1863.7
3	92.3	144.7	+52.3	2739.5
4	234.0	311.5	+77.5	6006.3
5	203.7	241.3	+37.7	1418.3
6	115.0	136.8	+21.8	476.6
7	59.3	64.5	+5.2	26.7
8	30.5	51.2	+20.7	427.3
Total	789.7	1061.8	272.2	13149.5

$S = 23.57$; $t = 3.60$; $df = 7$

From Fig. 13 the least mean leaf area of 4.1 cm^2 was recorded on block six for the progenies of flowers visited by *Megachile* sp. whilst the highest mean value of 8.4 cm^2 was recorded on block one. In the case of the progenies of unexposed (control) flowers the least mean leaf area was 16.7cm^2 and was recorded on the second block whilst the largest leaf area (21.2 cm^2) was recorded on block five. The differences between the means for the progenies of unexposed flowers and that of flowers visited by *Megachile* sp. were very highly significant ($t = 12.41$; $P = 0.001$; $df = 5$).

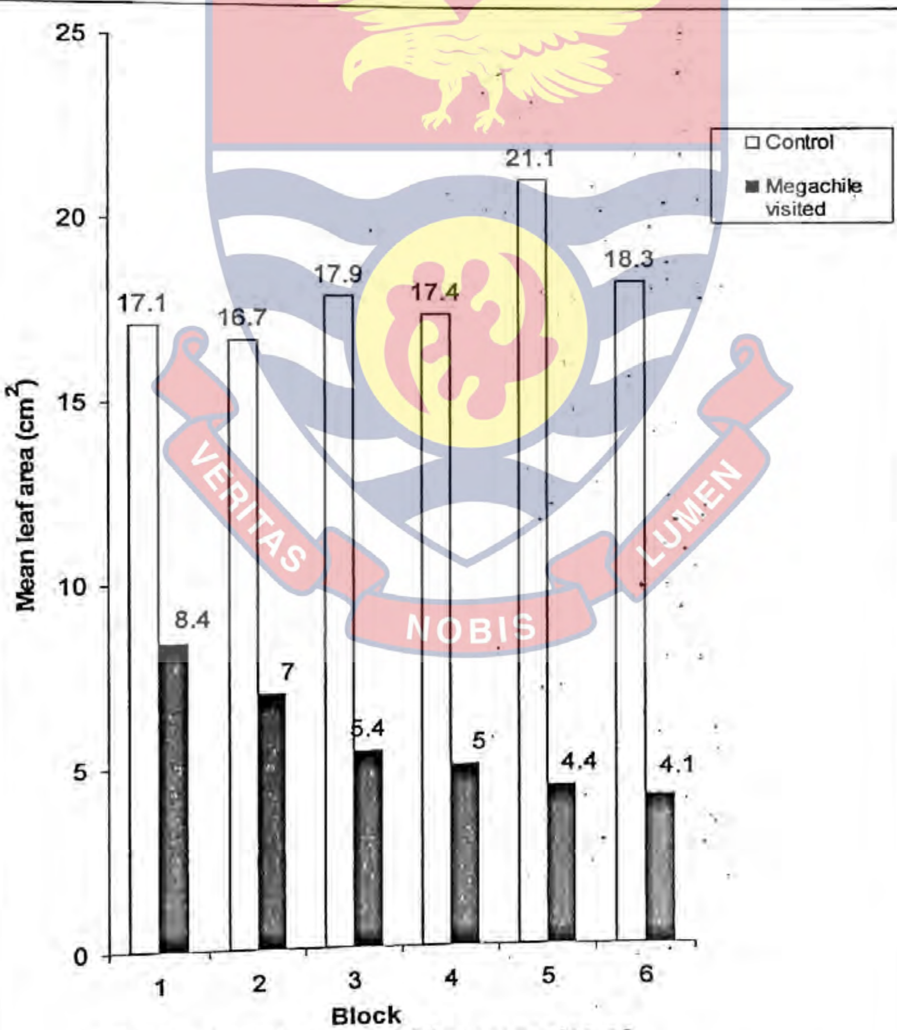


Fig. 13: Mean leaf area of the progenies of flowers visited by *Megachile* sp. and control flowers per block

The graph of chlorophyll fluorescence induction kinetics is shown in Fig.14. The calculated fluorescence decrease ratios (Rfd) are also shown in table 25. The Rfd for the progenies of flowers that were not exposed to organisms was 0.9 whilst that of the progenies of flowers visited by *Megachile* sp. was 0.8. The Rfd level shows photosynthetic efficiency of a leaf. Hence, the results showed that the leaves of the progenies of unexposed flowers were more photosynthetically efficient than those of progenies of flowers visited by *Megachile* sp.

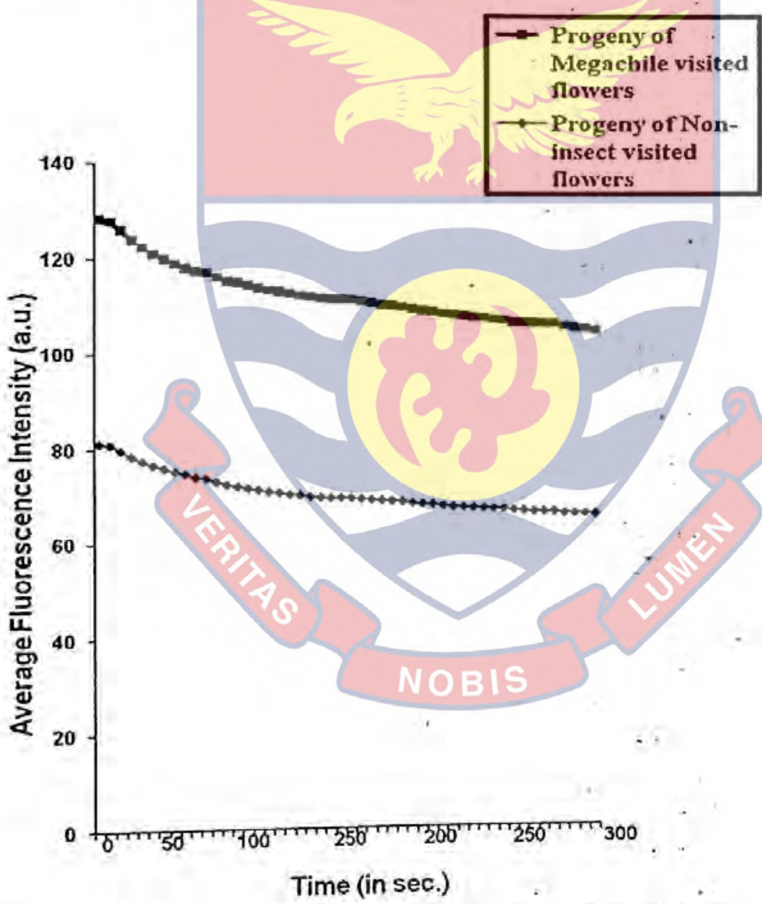


Fig. 14: Chlorophyll fluorescence induction kinetics of the progenies of seeds obtained from non-insect visited and *Megachile* visited flowers

Table 25: Mean values of the chlorophyll fluorescence induction kinetics

Chlorophyll fluorescence induction kinetics parameter	Progenies of unexposed (control) flowers	Progenies of flowers visited by *Megachile sp.*
Maximum fluorescence (Fmax) intensity	47.3	81.1
Steady-state fluorescence (Fs)	25.2	44.0
Fluorescence decrease (Fd)	22.1	37.1
Fluorescence decrease ratio (Rfd)	0.9	0.8

The progenies of flowers not exposed to organisms (control) recorded the highest number of pods (494 pods) on block four followed by block three (407 pods). On the other hand the progenies of flowers visited by *Megachile* sp. recorded the highest number of pods (667 pods) on block two followed by block three (636 pods). In both cases the least number of pods were recorded on block six (Table 26). The differences between the observed and expected total number of pods were very highly significant ($\chi^2 = 133.33$; P = 0.01; df = 5). The total number of pods for the progenies of control flowers was 2163 while that of the progenies of flowers visited by *Megachile* sp. was 2986.

Table 26: Total number of pods per block for the progenies of control and flowers visited by *Megachile* sp.

Type of progeny	Number of pods / block						
	1	2	3	4	5	6	Total
Progenies of control (unexposed) flowers	310	365	407	494	352	235	2163
Progenies of flowers visited by *Megachile* sp.	325	667	636	429	431	298	2986
Total	835	1032	1043	923	783	533	5149

$\chi^2 = 133.33$; df = 5

The highest fruit abortion value for progenies of control or unexposed flowers was recorded on block five while the least was on block three. Also, progenies of flowers visited by *Megachile* sp. recorded the highest fruit abortion on block one and the least on block four (Table 27). The differences between the means of the two types of progenies were not significant ($t = 2.23$; $P = 0.05$; df = 5). In all, progenies of flowers visited by *Megachile* sp. recorded higher fruit abortion than progenies of control or unexposed flowers.

Table 27: Mean fruit abortion per week per block for the progenies of control and flowers visited by *Megachile* sp.

Block	Mean fruit abortion per each type of progeny		Deviation $(X_2 - X_1)$ D	Deviation squared (D^2)
	Control (unexposed flowers) (X_1)	Flowers visited by *Megachile* sp. (X_2)		
1	48.5	106.4	+57.8	3350.1
2	54.5	76.9	+22.4	500.9
3	42.5	78.4	+35.9	1287.4
4	52.5	52.1	-0.4	0.1
5	63.6	74.9	+11.3	126.6
6	60.3	58.4	-1.4	1.9
Total	321.9	447.0	125.7	5216.9

$S = 8.30$; $t = 2.23$; df = 5

The number of seeds per pod ranged between 4 and 15. In both cases the highest number of pods bore seeds ranging between 10 and 12. However, the progenies of flowers visited by *Megachile* developed a higher number of pods (201 pods) bearing seeds ranging from 10 to 12 compared to progenies of unexposed flowers (151 pods). Similarly, progenies of the flowers visited by

Megachile sp developed more pods (78 pods) with 13 to 15 seeds than progenies of unexposed flowers (51 pods) (Table 28). The differences between the observed and expected frequencies for both types of progenies were very highly significant ($\chi^2 = 45.86$; P = 0.01; df = 3).

Table 28: Number of pods per number of seeds/pod for the progenies of the control and flowers visited by *Megachile* sp.

Number of Seeds/pod	Number of pods per number of seeds for each type of progeny	
	Progenies of control (unexposed flowers)	Progenies of flowers visited by *Megachile* sp.
4 – 6	80	23
7 – 9	138	118
10 -12	151	201
13 – 15	51	78
Total	420	420
$\chi^2 = 45.86$; df = 3		

For the progenies of unexposed flowers, the highest number of seeds out of 70 pods was recorded on block two (708 seeds and mean of 10.11). Contrarily, the highest number of seeds out of 70 pods (822 seeds and average of 11.7) was recorded on block one for the progenies of flowers visited by *Megachile sp.* In all, progenies of flowers visited by *Megachile* sp. recorded higher number of seeds out of 70 pods than progenies of unexposed flowers (Table 29). The differences between the observed and expected total number of seeds were very highly significant ($\chi^2 = 176.09$; P = 0.01, df = 5) and the differences between the means of the two types of progenies were also highly significant (t = 4.33; P = 0.01; df = 5).

Also, the progenies of flowers visited by *Megachile sp.* developed longer seeds than the progenies of unexposed flowers (Fig. 15). Similarly, the progenies of flowers visited by *Megachile* sp. developed seeds with bigger circumference than progenies of unexposed flowers (Fig. 16).

Table 29: Seed count for the progenies of the control and flowers visited by *Megachile* sp. per block

Block	Total number of seeds from 70 pods		Mean number of seeds per pod	
	Progenies of control	Progenies of flowers visited by *Megachile* sp.	progenies of control	Progenies of flowers visited by *Megachile* sp.
1	628	822	9.0	11.7
2	708	769	10.1	11.0
3	642	749	9.2	10.7
4	650	728	9.3	10.4
5	605	634	8.6	9.1
6	606	704	8.7	10.1
Total	3839	4406	54.8	63.0
	χ^2 = 176.09 ; df = 5		t- test = 4.33 ; df = 5	

The roots of the progenies of the flowers visited by *Megachile sp.* developed higher number of nodules than the roots of the progenies of unexposed flowers (Fig. 17). The highest number of nodules (61.7 nodules) was recorded on block two followed by block three (57.0 nodules) and block five. The differences between the means for the two types of progenies were highly significant (t = 5.82; P=0.005; df = 5).

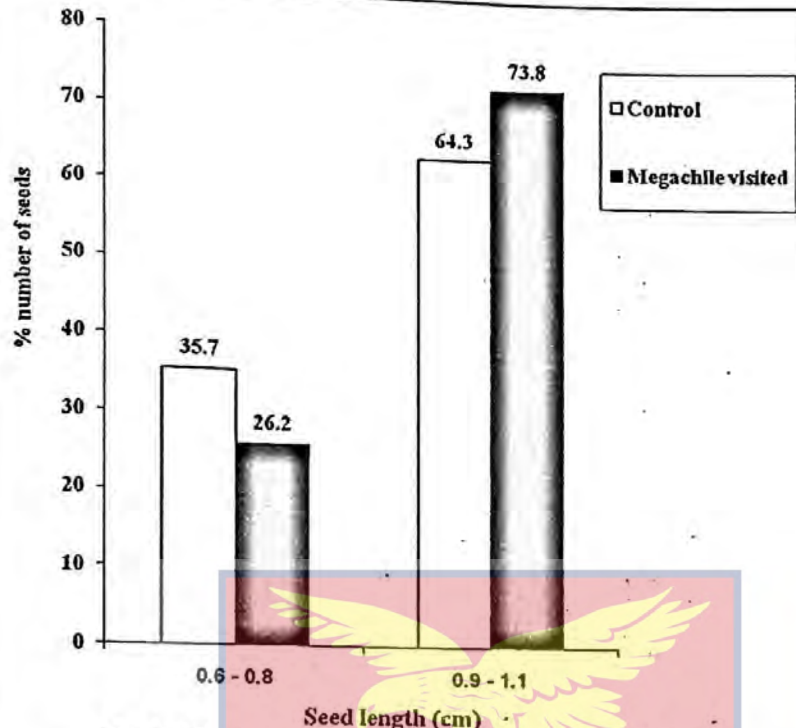


Fig. 15: Percentage number of seeds per length for the progenies of flowers visited by *Megachile* sp. and control flowers

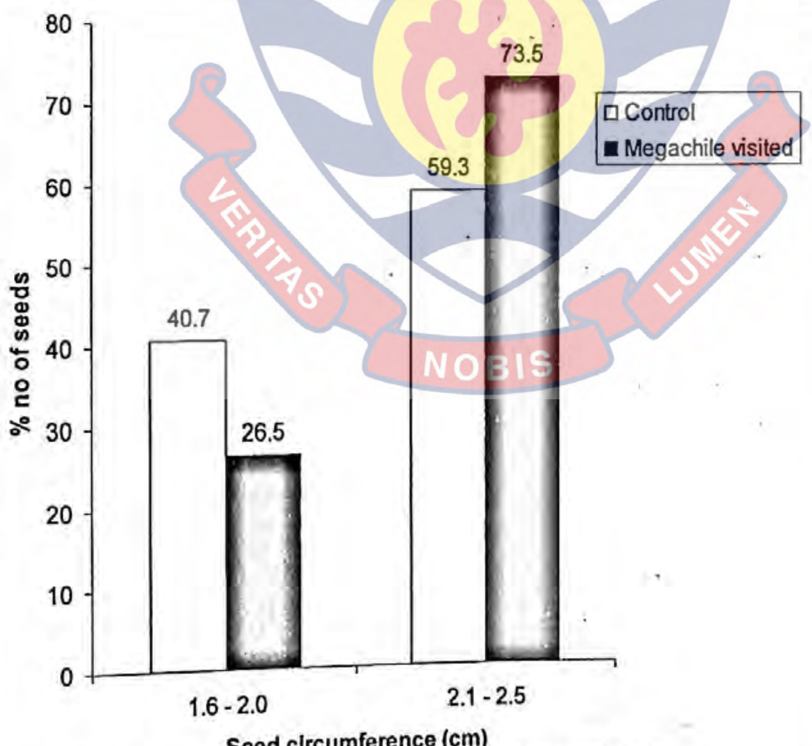


Fig. 16: Percentage number of seeds per seed circumference for the progenies

Results of nutrient analysis showed that progenies of unexposed flowers (control) generally contained higher levels of starch than progenies of flowers visited by *Megachile* sp. (Table 30). The differences between the means for the two types of progenies were highly significant (t = 6.43; P = 0.01; df= 5). However, progenies of flowers visited by *Megachile* sp. generally contained more calcium than progenies of unexposed flowers. The differences between the means for the two types of progenies were significant (t = 3.83; P =0.05; df = 5).

Also, progenies of the flowers visited by *Megachile* sp. produced more phosphorus than progenies of the unexposed flowers. The differences between the means for the two types of progenies were very highly significant (t = 21.30; P =0.001; df = 5). On the other hand the progenies of unexposed flowers recorded higher fibre content levels than progenies of flowers that were visited by *Megachile sp.* The differences between the means for the two types of progenies were highly significant (t =4.37; P = 0.01; df = 5). For protein, progenies of flowers visited by *Megachile* sp. recorded higher values than progenies of unexposed flowers (Table 30). The differences between the means for the two types of progenies were very highly significant (t = 12.48; P = 0.001; df = 5).

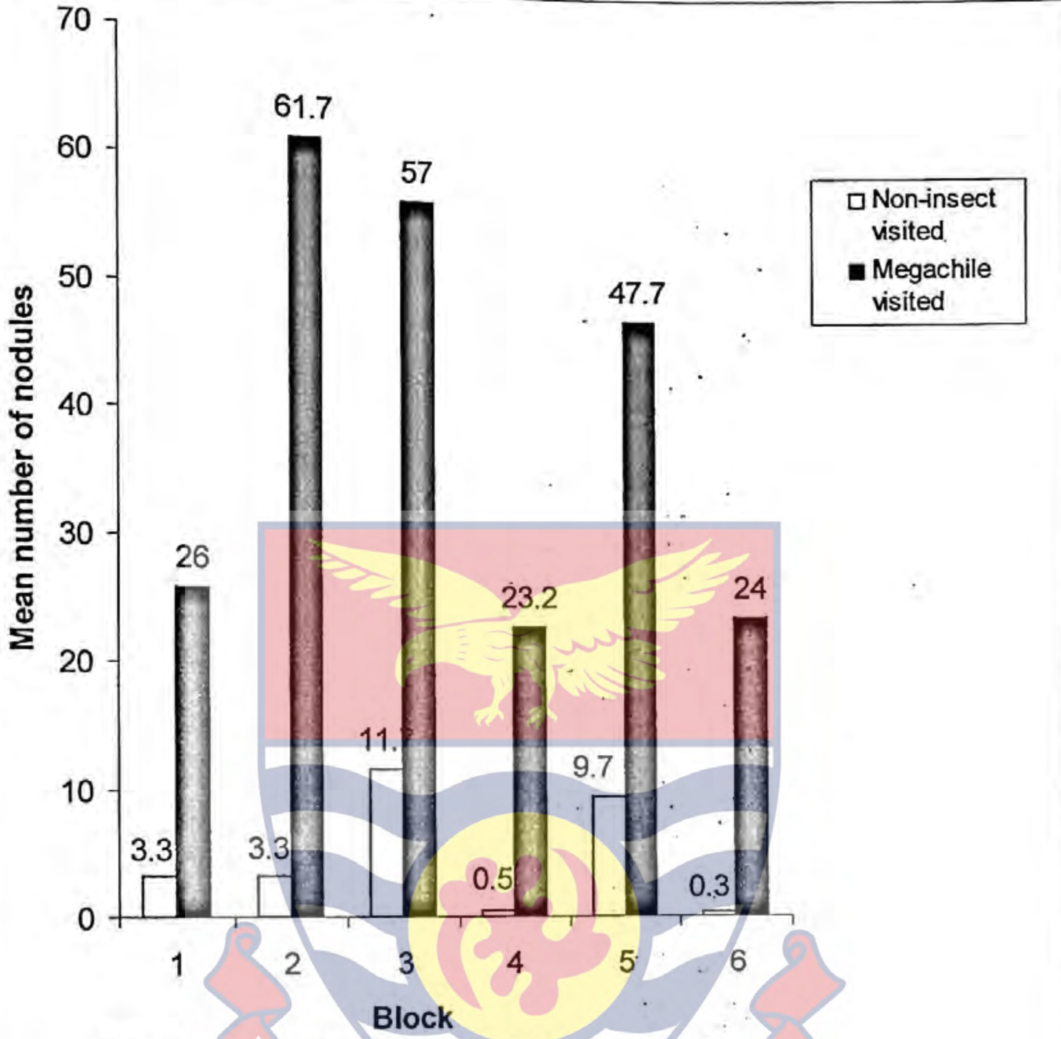


Fig. 17: Mean number of nodules per plant for the progenies

Table 30: Mean nutrients content of the seeds of the progenies of unexposed flowers (control) and flowers visited by *Megachile* sp.

Block	Starch (in Mg/kg)		Calcium (in Mg/kg)		Phosphorus (in Mg/kg)		Fibre (in Mg/kg)		Protein (in Mg/kg)	
	PUF	PFVM	PUF	PFVM	PUF	PFVM	PUF	PFVM	PUF	PFVM
1	367.3	352.9	2.1	2.4	5.3	6.1	26.5	25.2	232.7	249.6
2	372.9	349.6	2.3	2.5	5.5	5.9	32.1	25.1	235.6	248.9
3	362.6	342.6	2.2	2.5	5.5	6.0	28.4	26.3	230.8	253.9
4	374.4	350.2	2.4	2.4	5.2	6.2	29.6	25.4	232.9	249.8
5	372.6	340.4	2.1	2.6	5.3	6.1	27.4	23.9	234.3	249.0
6	369.2	340.7	2.2	2.4	5.5	6.0	27.7	24.6	234.0	252.1
t-test value	t = 6.43		t = 3.83		t = 21.30		t = 4.37		t = 12.48	

PUF = Progenies of Unexposed Flowers (Control)
PFVM = Progenies of Flowers Visited by *Megachile* sp.

CHAPTER FIVE

DISCUSSION

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors within the cowpea agro-ecosystems

According to the World Bank Group (1999), in Ghana, owning of enterprises enables women to meet their immediate needs, augment their earnings from agricultural activities, and acquire resources for future investments. In this study, almost all the farmers (80.8%) and Agricultural Extension Officers (86.4%) were males. The finding that more men (80.8%) than women (19.2%) were involved in cowpea farming contradicts the assertion by Uganda Peoples Congress (1985) that women contribute more efforts in the production of food and other crops. However, the finding that almost all (86.4%) the Extension Officers were men confirm the observation by Uganda People's Congress (1985) that almost all Agricultural Extension workers, cooperative extension workers, veterinary extension workers, and all trade development officers are men.

This study showed that majority of the farmers fall within the age group 12 to 55 years. However, a large number of these were between 15 and 45 years. This suggests that many of the cowpea farmers are still young and energetic. Similarly, the fact that majority of the Extension Officers fall between the ages of 26 and 45 years implies that they are still young and energetic to carry on with their work. Similar results were obtained by Munyua and Adams (2006) when they assessed the perception of Agricultural Extension Officers on Integrated Pest Management (IPM) in Uganda. Since majority of the farmers (98.08%) had one form or other of formal education it is envisaged that in their science lessons they would have acquired some knowledge pertaining to pollination and pest control. Hence, whenever they are educated on issues of pollination and pest control these farmers may be able to understand it very easily.

In this study it was found out that majority of the Extension Officers (81.8%) obtained General Certificate in Agriculture. Such low academic qualification of majority of the Extension Officers can make them a little deficient in understanding the scholarly findings of agricultural research officers. Hence, this can negatively affect their efficiency. This finding is in line with what Muchena *et al.* (1999) wrote that about 83% of extension professionals in Ghana hold only a certificate in agriculture and they are employed at the technical officer level and for most the possibility of continuing their education is practically non-existent. FAO (1996) also contended that there is a shortage of well-trained Agricultural Extension staff in many developing countries. Zinnah *et al.* (1999) also confirmed this by saying that Agricultural Extensionists constitute the least-trained group of staff in African Agricultural Organizations. Their initial formal training is usually inadequate and where in-service training is provided it is often ad hoc and not responsive to the changing nature of extension tasks. Judging from the results, it can be deduced that the initial training of the Extension Officers is inadequate. Meanwhile, FAO (1990) also stated that a large number of African extension staff (56%) possess secondary school-level academic qualifications. However, FAO (1990) did not go further to explain the adequacy of secondary school academic qualification for effective operation of Extension Officers.

It is also clear that majority of the farmers (71.2%) have very few years of experience in cowpea farming (1-5 years). Hence, if they cannot get the needed advice then they may be tempted to adopt farming practices that will not lead to high yields and can negatively affect the environment including probable cowpea pollinators. On the part of the Extension Officers, majority of them have between 6 and 30 years experience in providing extension services. This can be an advantage if the officers can learn on the job. That way, even the low professional and academic qualification of majority of them may not have much negative impact on their performance.

Concerning the acreage, majority of the farmers do less than 11 acres of cowpea farms a year. This shows that the crop is mainly cultivated at a subsistence level in the research areas. Singh and Tarawali (Internet - http://www. cgiar.org/ InfoServ/Webpub/Fulldocs/Cropresidues/chap%204.htm) reported similar findings where they stated that cowpea is primarily grown in mixtures with cereals especially maize in the moist savanna and sorghum and millet in the dry savanna. Quin (1997) also observed that on-farm cowpea yields in West Africa average 240 kg/ha. According to Arodokoun (1996) and Bottenberg *et al.* (1997), in West Africa, cowpea is cultivated mainly as rainfall crop from April to November, depending on the location. International Institute for Tropical Agriculture (IITA) (Internet) also observed that traditionally, in West and Central Africa, cowpea is grown on small farms, often intercropped with cereals such as millet and sorghum. Hence, the current finding is just confirming the fact that in West Africa and for that matter the three districts of Ghana cowpea farming is still in the hand of subsistent farmers. No doubt, it is common to find very small cowpea farms in the three districts.

Agricultural information plays a central role in the very survival of farmers and fishermen in Ghana. The dependence on information related to agriculture will continue to shape the attitude towards meeting new demands and responsibilities as the nation strives to join the global village (Dziwornu, 2003). However, the low farmer / Extension Officer ratio and the subsequent unified Agricultural Extension arrangements have brought challenges to farmers (Dziwornu, 2003). The assertion by Dziwornu is not far different from the finding of this study showing that individual Extension Officers have large number of farmers (81+) under them. With these large numbers, if the Extension Officers are not able to devise any workable strategy then they may not be able to take good care of all the farmers. Hence, the farmers will be left to practice what they know best to the detriment of high productivity and the environment as well as probable pollinators. This finding also corroborates the assertion by FAO (1990) that in developing countries the estimated extension-staff-to-farmer ratio was more than 1:2000. FAO/DFID/ODI (2002) also reported that in the Komenda-Edina-Eguafo-Abrem (KEEA) district the Extension Officer to farmer ratio is 1:5000. In this study the ratio varies and the highest Extension Officer to farmer ratio is 1:80 or more. Given the low numbers of extension staff, accompanied by low levels of training, it is not surprising that extension organizations are functioning poorly in Africa (Zinnah *et al.*, 1999). A more worrying situation under this study is the number of officers who do not know the number of cowpea farmers under their control. This is difficult to explain, but only to say that it may mean that they have lost track of their professional job and are doing something else or they do not promote the cultivation of cowpea in their areas of control.

The cowpea flowers are often visited by honeybees or bumble bees (Robbins, 1931) and various other insects that forage upon both the nectar and pollen. In this study, it is only lepidopterans (butterfly and moth) that almost 50% of the farmers claimed to visit the cowpea flowers. Meanwhile, all the insects presented to the respondents one time or the other visit the cowpea flowers. This suggests that the farmers lack information about the role of insects presented to them on cowpeas. According to FAO/DFID/ODI (2002), agriculture makes 40% of GDP and 70% of rural employment. The opportunity exists to improve information for livelihoods through a number of different policies, institutions and processes involved in agricultural information provision in the country (FAO/DFID/ODI, 2002). Dziwornu (2003) opined that although various NGOs operating in Ghana have been trying to solve the information needs of farmers, a lot of efforts need to be put in place. As farm incomes continue to fall, and rural poverty is on the increase, the need to do things in different ways and forms becomes very necessary. It is a fact that the information gap among farmers is wide and has affected the farmers to the extent that farm holdings are shrinking on annual basis (Dziwornu, 2003). Hence, the low knowledge of the cowpea farmers about these insects visiting the cowpea flowers may be due to the fact that they (farmers) do not normally pay attention to flower visitors or they might be observing these visitors on the flowers but might not have known the distinction between them.

For Extension Officers, bees and lepidopterans received positive response from them (Extension Officers) as insects that normally visit the cowpea flowers. Boateng (2006) asserted that an effective knowledge management strategy for Agricultural Extension practice must aspire to bring the communities of extension experts and farmers together in all the knowledge management phase from knowledge creation to utilization. The results under discussion show that both farmers and the Extension Officers do not have much knowledge about the kinds of insects that normally visit the cowpea flowers.

The extra-floral nectarines at the base of the corolla of cowpea flowers attract ants, flies, and bees, but a heavy insect is required to depress the wings and expose the stamens and stigma (Purseglove, 1974). In responding to what specifically some selected insects do on the cowpea flowers majority of both farmers and Agricultural Extension Officers accepted bees and lepidopterans as pollinators. In addition to that the Extension Officers stated that flies are pests. Generally, large numbers of both farmers and Extension Officers did not respond to show whether some of the insects are predators, pollinators or pests. Similarly, both groups scored low figures in considering the insects as predators. The responses from this study suggested that respondents did not know or were not sure what exactly the insects presented to them do on the cowpea flowers. However, Isubikalu *et al.* (1999) reported that Kenyan cowpea farmers explicitly stated that aphids (*Aphis craccivora*), pod borers (*Maruca vitrata*) and different pod sucking bugs (Hemiptera) were the most important pests of cowpea. Other insect pests mentioned by cases were foliage beetles (*Ootheca mutabilis*), flower beetles (*Mylabris* spp.), and thrips (*Megalurothrips sjostedti*). In this study also, beetles were considered by farmers as pests. Isubikalu *et al.* (1999) went on to observe that Kenyan cowpea farmers considered aphids to be the most important pest of cowpea particularly at the vegetative stage prior to flowering. Subsistence farmers, who grew cowpea primarily for leaf harvest, also ranked foliage beetles as very important pests (Isubikalu *et al*, 1999). Meanwhile, International Institute of Tropical Agriculture (IITA) (Internet) and Tamp *et al* (1993) also asserted that the major pests attacking cowpea plants are flower thrips (*Megalurothrips sjostedti*), pod borer (*Maruca vitrata*), and pod sucking bugs. Thus, flies have not been cited as pests. However, in this study many farmers (34.6%) and Extension Officers (68.2%) considered flies as pests.

It is clear from this study that most of the farmers (98.0%) and all the Extension Officers have knowledge of the existence of pollinators. This appears very encouraging. Meanwhile the New Agriculturist (2006) asserted that in the face of much reduced public expenditure, extension services in Sub-Saran Africa have a daunting challenge: farmers' need for information is as high as ever, but the resources to provide it are meager at best. Similarly, in the words of Boateng (2006), for improved agricultural productivity based on suitable practices, a new approach to knowledge management in Agricultural Extension practice becomes critical. Such an approach should aim at connecting Agricultural Extension experts and farmers as a precursor to improved knowledge utilization in agricultural practice (Boateng, 2006). Therefore, it is good that both cowpea farmers and the Extension Officers indicated that they are aware of the existence of what is called pollinators. This is because, insufficient knowledge among farmers, Extension Officers and any pest control operators about pollinators and pollination processes can hinder the conservation and sustainable use of natural pollinators (Ahmad *et al*., 2006). Therefore, further understanding of the issues of pollinators and pollination can be addressed by building capacity through informational networks among farmers, Extension Officers, development agencies and researchers.

Knowledge can be formal (explicit) or informal (tacit). Formal knowledge is based on scientific evidence, whose validity and reliability can be tested over a reasonable period of time. Informal knowledge is experiential in nature and it is acquired after an exemplary practice has been put to use over a period of time (Boateng, 2006). Informal knowledge, unlike formal knowledge is difficult to replicate because the means for its acquisition is difficult to share (Boateng, 2006). In this study the high percentage of the farmers having knowledge of the existence of pollinators may be due to the fact that almost all of them (farmers) have had one kind or the other of formal education. It may also be due to their practical experience over the years, which is classified as indigenous knowledge. Indigenous knowledge is local knowledge that is unique to a given culture of society (Warren, 1987). Indigenous knowledge can also be described as the systematic body of knowledge acquired by local people through the accumulation of experiences, informal experiments, and intimate understanding of the environment in a given culture (Rajasekaran, 1993). Indigenous knowledge is also considered to be the actual knowledge of a given population that reflects the experiences based on traditions and includes more recent experiences with modern technologies. However, in this study it is not surprising at all when all the Extension Officers claimed to have heard of pollinators. This is because they (Extension Officers) are expected to have more formal knowledge of a subject matter such as pollination so that they can adequately educate the farmers on it (Rajasekaran, 1993). The custodians of indigenous knowledge systems include local people such as farmers, landless labourers, women, rural artisans and cattle rearers, etc. These people are well informed about their own situations, resources, what works and what does not work, and how one change impacts other parts of their system (Butler and Waud, 1990). Such knowledge though not scientifically acquired can be acquired over the years and since it is experiential an individual farmer can exhibit it to the extent that people will think that he/she acquired it through any formal education.

Eardley (2002) observed that animals that provide plants the services that cause fertilization or movement of pollen to receptive stigma of another plant are called pollinators. Abrol (1997) described pollination as the transfer of pollen grains from male to female reproductive structures of plants. It is very encouraging to note that majority of the farmers (98.1%) and Extension Officers (88.6%) agreed that pollinators transfer pollen grains from the anther to the stigma. This may also be due to the formal education that many of the farmers had or their field experience. In the case of the Extension Officers it is expected that they would have high level of explicit knowledge of the subject of pollination so that they can advise the farmers. Similar sentiments were expressed by the World Bank Group (2004) when they stated that national extension agencies were organized to transfer standard technologies to farmers throughout the country. Over time, such services from the officers often proved inefficient and made it difficult for programmes to be responsive to clients. Extension increasingly has been required to provide location-specific services to improve management and efficiency of input use, conserve natural resources, support diversification and value-added production, respond to community or farmer-specific interests, and provide non-farm information services relating to poverty reduction (World Bank Group, 2004). However, under this study it should be a source of concern when some Extension Officers (11.4%) indicated that pollinators destroy flowers. This implies that such officers lack knowledge so far as the definition and the role of pollinators are concerned. Generally, these were officers who had General Certificate in Agriculture.

Another source of concern is the fact that many of the farmers (42.31%) and some Extension Officers (13.64%) rated their personal knowledge of pollinators below 40%. More worrying is that of the Extension Officers because if they do not know then the farmers cannot easily get the necessary advice that will enable them to derive the best benefit from pollinators. These findings proved the points made by Ahmad *et al*. (2006) which emphasize the need for training in introductory courses in pollination and pollinators for agriculture in primary and secondary schools. They also recommended introductory courses in pollinator identification, biology and conservation using an ecosystem approach in agricultural colleges (Ahmad *et al*., 2006).

According to Roling (1992), the over-reliance on scientific knowledge and Agricultural Extension practice has long been identified as an impediment to increased agricultural productivity. Despite the setbacks associated with this, the emphasis continues to be placed on improving the intervention capacity of extension services such as more staff, facilities and logistics while the capacity to actively involve, listen to and engage farmers' tacit knowledge in extension practices remain neglected (Roling, 1992). Judging from the results in this study, there is the need to organize some kind of training for cowpea farmers and Extension Officers in pollination and pollinator identification, biology and conservation. For the farmers, advantage can be taken of their indigenous knowledge systems such that the adaptive skills of the farmers that were derived from many years of experience and oral communication can be tapped and improved upon for training in pollination and pollinator conservation, biology and identification.

In this study, though all the points presented to the respondents as benefits of pollination are correct and acceptable, the farmers and Extension Officers mainly agreed on increased fruit set or increased crop yield as the benefit of pollination. This implies that the other benefits of pollination presented are not popular with respondents. This is at variance with what Abrol (1997) wrote that cross-pollination brings about hybrid effects in plants progeny leading to qualitative and quantitative changes in the development of the plants. Some of such quantitative and qualitative changes are stimulation of germination of pollen on stigmas of flowers, increase in viability of seeds, embryos and plants, formation of more nutritive and aromatic fruits and increase in the vegetative mass and faster growth of plants. Other benefits of cross-pollination are increase in the number and size of seeds and yield of crops, increased nectar production in the nectaries of plants, increased fruit set and reduction in fruit drop, enhanced resistance to diseases, and increased oil content in oil seed crops (Abrol, 1997). On the contrary, in this study apart from agreeing to benefit of increase fruit set or increased crop yield by farmers and Extension Officers as well as increased fruit viability by Extension officers, both groups of respondents disagreed with all the other benefits presented to them.

The fact that both farmers and Extension Officers agreed that pesticide application destroys flower visitors and pollinators suggest that both farmers and Extension Officers are aware of the negative effects of pesticide applications on beneficial insects in cowpea farms. This is good, especially in the case of the farmers because if they can put this knowledge into use they may not indiscriminately spray chemicals. They may take precautions to avoid killing beneficial insects in cowpea farms.

In this research it is important to take note of the point that majority of the farmers (96.2%) and all the Agricultural Extension Officers agreed that farmers should be given training in the knowledge of pollinators and their usefulness. After all, one important factor that can bring about new ways of thinking and innovation among farmers and Extension Officers is training. Therefore their responses show the importance that both cowpea farmers and Extension Officers attached to the subject of pollination. Hence, it is important for the Ministry of Food and Agriculture (MOFA) to see to such training for the farmers. However, considering the kind of response received from Extension Officers pertaining to the knowledge covering insect pollinators, it will be advisable to do a number of weeks' intensive courses for the Extension Officers separately on the issue of insect pollinators. In any case the services provided by Agricultural Extension Officers help members of a farming community to become more self-reliant and independent (Carrers.co.za, Internet). This is also because farmers believe that the fundamental function of Extension Officers is to educate them (Boateng, 2006). Perhaps there is the need for reforms in the extension service that will help farmers to have access to extension services as observed by Garforth *et al* (1998). Ahmad *et al* (2006) also observed that there is the need for hands-on training for farmers and Extension Officers in the conservation and sustainable use of pollinators in agricultural landscapes. Actually, farmers and Extension Officers need training in the technical skills in determining the economic values of pollinators and the detrimental effects of pesticide use on pollinators (Ahmad *et al.*, 2006). Such training for both parties should focus on improving the economic and social benefits through increasing yield and improving produce quality and management practices. Also, there should be the teaching of the causes and effects of insufficient pollinator biodiversity (Ahmad *et al.*, 2006).

When asked to give reasons why farmers should be given training in the knowledge of pollinators and their usefulness, Extension Officers believed that it will help farmers to know the importance of pollinators and not to destroy them; because farmers do not know the difference between pests and pollinators; because it will help learners to know how to identify pollinators and other useful insects; and because farmers do not know much about pollinators and their usefulness. These points advanced by the respondents are very important because if the farmers have such kind of knowledge about pollinators they may make the attempt of preventing their destruction. When asked whether they organize the training for the farmers 86.4% (38) Extension Officers responded in the affirmative whilst 13.6% (6) of them were negative. The high percentage of Extension Officers who agreed that they do organize the training for the farmers is very encouraging provided they actually do it. Those officers who claimed to have been organizing the training for the farmers stated topics such as insect pest control measures, types of pollination agents, the right time to spray chemicals, right dose of chemicals to spray, and the need to carry beehives to farms during flowering as those that they normally treat with their farmers. However, one is tempted to ask whether these things are actually done for the farmers. The reason is that day-to-day activities of the farmers suggest that they have very little knowledge if any at all about the kind of things the officers claimed they have been taking them through.

Those Extension Officers who indicated that they do not organize the training for their farmers stated lack of time for the officers themselves and limited knowledge in pollination issues by officers themselves as some of the reasons why they do not organize such trainings for their farmers. Here it may be odd to accept the idea of lack of time on the part of the Extension Officers to organize the training for the farmers because generally, this is one of their core businesses. However, the idea of limited knowledge of the officers themselves about pollination and pollinators need to be taken seriously by the Ministry of Food and Agriculture to make sure that the officers are given in-service training on the subject. In response to what is done when pests infest the crops, 94 farmers (90.4%) and 36 Extension Officers (81.8%) asserted that the crops are sprayed with chemicals. Isubikalu *et al.*

(1999) also reported similar findings from Uganda where they stated that cowpea farmers preferred to use pesticides, as the primary method of pest control. The findings of this study confirmed what Alghali (1991) stated that applications of insecticides can control pests and increase cowpea yields. Fatokun (Internet - http://www.iita.org/details/cowpea-pdf/cowpea-1.-5.pdf) also asserted that relatively high grain yields can be obtained with two or three insecticide sprays. Efficient control of insect pests can increase grain yield five times or more (Ghana/CIDA Grain Development Project, 1988; Adu-Dapaah *et al.*, 2005). In addition to following recommended cultural practices and practicing crop rotation, it is important to spray the crop with insecticides to protect against insect pests (Ghana / CIDA Grain Development Project, 1988). Ghana/CIDA Grain Development Project (1988) went on to state that the use of insecticides on the improved varieties of cowpea is strongly recommended. Therefore, farmers who do not spray their fields risk a total crop failure. The highest yields will always be achieved through the use of improved varieties and the recommended insecticides (Ghana/CIDA Grain Development Project, 1988). The implication of the above findings and submission is that some form of chemical application is required in times of pest infestation on cowpea farms.

Out of the 94 farmers who agreed on chemical applications, 47 (50.0%) and 31 (33.0%) stated that chemicals are sprayed twice and once respectively during a cropping period. On the part of Extension Officers 19 (52.8%) and 11 (30.6%) indicated that chemicals are sprayed once and twice respectively. In order to control pre-flowering insect pests two chemical sprays are done (Ghana/CIDA Grain Development Project, 1988; Awuku *et al.*, 1991 and Adu-Dapaah *et al.*, 2005) for extra early, early and medium yielding varieties. For medium maturing varieties post-flowering sprays can be done once (Adu-Dapaah *et al.*, 2005) or twice (Ghana / CIDA Grain Development Project, 1988, and Awuku *et al.*, 1991). Therefore it can be said that the cowpea plants can be sprayed at least three times or four times on average before harvesting. Fatokun (Internet - http://www.iita.org/details/cowpea-pdf/cowpea-1.-5.pdf) also indicated that relatively high yields can be obtained with two or three insecticide sprays. Judging from the result of this study it seems both farmers and Extension Officers are having the same opinion. Their responses clearly showed that both farmers and Extension Officers do not know exactly how many times the cowpea plants need to be sprayed before harvest. This does not augur well for high cowpea yield because it may be possible that wrong applications might be taking place which will not favour high yield. No doubt cowpea production is still at highly subsistence level in the research areas. Since, chemical application goes with a lot of environmental hazards including destruction of pollinators, it will be very prudent if the Ministry of Food and Agriculture can contract experts to train both farmers and Extension Officers in the best practices of cowpea pest control.

In this study the results showed that 69.2% of cowpea farmers are not aware that synthetic pesticides can cause the destruction of insect pollinators. However, all the Extension Officers agreed that synthetic chemicals can kill insect pollinators. Views similar to that of the Extension Officers have been articulated by several authors. For example pesticide application has become a big menace to pollinators (Buchmann and Nabhan, 1996). The poisoning of honeybees and other beneficial insects by pesticides can be a serious problem. The most serious problems occur when bees collect contaminated pollen or nectar and carry these materials back to the hive. Insecticidal dusts and encapsulated insecticides such as Penncap-M are especially dangerous because they adhere to foraging bees and may be collected and stored in the hive with pollen. Such materials can cause serious bee kills within the hive for many months (Richard, 1996). Pesticide misuse has driven beekeepers out of business, but can affect native wild bees even worse, because they have no human to move or protect them. Bumblebees are hit over and over when pesticide applicators apply insecticides on blooming cotton fields while the bees are foraging. Widespread aerial applications for mosquitoes, med-flies, grasshoppers, gypsy moths and other insects leave no island of safety where wild insect pollinators can reproduce and repopulate. One such programme can knock down pollinator populations for several years (Wikipedia, 2004). Considering the low grading the farmers put on their personal knowledge in pollination and pollinator services, it is not so surprising that majority of them do not know that chemical pesticides can kill insect pollinators.

About the issue of whether other insects apart from pests are killed by the chemicals, 52 (55.3%) of the farmers agreed whilst 42 (44.7%) said that only the pests are killed. However, all the Extension Officers indicated that only the pests are killed. This result from the Extension Officers contradicts their earlier response that pollinators are killed when chemicals are applied. After all pollinators can also be insects. It also exposes the weaknesses of the Extension Officers. This is because pesticide application cannot kill only the insect pests but will definitely kill some of the other insects found on the plant including the beneficial insects.

Concerning the flower visitors, apart from pests that are killed by chemical application majority of the farmers agreed on ants, beetles and flies whilst Extension Officers generally agreed on all the insects except wasps. Here again the Extension Officers exhibited higher knowledge than the farmers. This is also expected because the Extension Officers are expected to have the necessary technical knowledge and transfer it to the farmers. However, it again contradicts the response that only pests are killed when chemicals are applied.

Whilst majority of the cowpea farmers agreed that the cowpea plants are sprayed during flowering stage, majority of the Extension Officers agreed on before flowering and at fruiting stages. For maximum yield pesticide sprays are done against pre-flowering pests and post-flowering pests (Ghana/CIDA Grain Development Project, 1988); Awuku *et al.*, 1991; and Adu Dapaah et *al.*, 2005). Therefore it can be said that the Extension Officers are aware of the right stage of the cowpea plant at which pesticide application in the cowpea agro-ecosystem should be done while majority of the farmers do not know. Here again, the Extension Officers can be indicted for the low knowledge of the farmers in this issue. This is because the Extension Officers are expected to educate the farmers on such issues. However, it may also be that the Extension Officers did their best but the farmers could not retain the correct stages of spraying in their memory. Apart from chemical control farmers could not generally agree on any other pest control measures whilst the Officers agreed that none of the methods stated was available to the farmers. On the other hand in a study under the title "Influence of Farmer Production Goals on Cowpea Pest Management in Eastern Uganda: Implications for Developing IPM Programmes" Isubikalu *et al.* (1999) reported that besides the use of pesticides farmers had local knowledge on alternative methods for controlling pests such as early planting, variety choice, weeding, leaf picking and intercropping. Fatokun (Internet - http://www.iita.org/details/cowpea-pdf/cowpea-1.-5.pdf) asserted that the high grain yields which can now be obtained with fewer insecticide spray regimes can be attributed to progress that has been made through genetic improvement whereby genes for resistance to some diseases and pre-flowering insect pests such as aphids have been incorporated into new cowpea varieties. Fatokun went on to say that there are cowpea lines that are resistant to the flower bud thrips (*Megalurothrips sjostedti*). Now a cowpea line has been identified as possessing the desired levels of resistance to the legume pod borer (*Maruca vitrata*) and pod sucking bugs (*Clavigralla tomentosicollis*, Anoplocnemis *curvipes*, and *Riptortus dentipes*) all of which are post-flowering pests (Fatokun, Internet).

The most economical and environmentally friendly way of controlling legume pod borer and pod sucking bugs would be through the host plant resistance (Fatokun, Internet -http://www.iita.org/details/cowpea-pdf/cowpea-1.-5.pdf). Perhaps, Integrated Pest Management (IPM) practices as prescribed by Adu- Dapaah *et al.* (2005) should be recommended for effective control of cowpea insect pests. This can include following recommended cultural practices. If that is done insecticide application should be done only when the pest population or damage is above economic threshold (Adu Dapaah *et al.*, 2005). However, a more pollinator friendly insecticide for controlling cowpea pests may involve the use of plant based extracts.

A typical example of such a plant based chemical is neem seed water extract (NSWE). Evidence from Annobil *et al.* (2006) indicates that the use of NSWE in managing cowpea insect pest complex at Juaboso in the Western Region of Ghana showed that neem seed extract and Cymethoate (Synthetic insecticide) significantly reduced the incidence of insect pest complex leading to drastic reduction of the damage caused to leaves and pods in treated plots. The evidence further indicates that the incidence of beneficial insects and other arthropods was higher on NSWE-treated plots than on Cymethoate-treated plots (Annobil *et al.*, 2006). This suggests that NSWE was less harmful to beneficial insects than Cymethoate (Annobil *et al.*, 2006). A number of authors attested to the fact that neem seed extracts are very potent against pests and friendly to useful organisms in the field (IPM of Alaska, 2003; USA Biopesticide and Pollution Prevention Division, 2005; Williams and Mansingh, 1996). Therefore, NSWE may be introduced to the cowpea farmers and the Extension Officers to experiment with to find out if cowpea pests can be controlled with minimal or no effect on pollinators.

The success of the Extension Service, to a large extent depends on how farmers are brought into the picture of knowledge management. However, the poor linkage between farmers and Extension Officers constitute a barrier for knowledge management to thrive (Boateng, 2001). The results of this study showed that 56 (53.9 %) of the farmers agreed that Agricultural Officers do advise them (farmers) on chemical control measures whilst 48 (46.2%) disagreed. Meanwhile, all the Extension Officers agreed that the farmers are advised by them (Agricultural Officers) on chemical applications. Here there seems to be a kind of high disparity in the percentage of farmers and Extension Officers agreeing to the same point. Here it seems one party did not tell the whole truth. It may be that the Extension Officers were trying to cover their inabilities by giving a positive answer.

Farmers who indicated that Agricultural Officers advise them on chemical control measures could not generally agree on any specific topic on which the training is centered whilst all the Extension Officers agreed on all the topics presented. Here, perhaps the Extension Officers are only exhibiting their academic knowledge but might not have been doing the education as they indicated.

In this study findings reveal that Karate, Actellic and Cymbush are the very popular chemicals to both cowpea farmers and Extension Officers as the common chemicals used on the cowpea farms. In all, the cowpea farmers stated more chemicals than the Extension Officers. Meanwhile, apart from lambda cyhalothrin

(Karate and PAWA), Cypermethrin (Cymbush, Cypercal), deltamethrin (Decis) all the other names given by the farmers are not recommended chemicals. Even DDT and Gammalin 20 are banned chemicals. Similarly, for the Extension Officers also not all the chemicals stated are recommended chemicals. Pre-flowering and flower insects are effectively controlled by spraying synthetic pyrethroids such as alphamethrin (fastac), Cypermethrin (Cymbush, Cypercal, Cypertex, Falcon), deltamethrin (Decis) and lambda cyhalothrin (Karate, Cyhalon, PAWA, Perfect) (Adu-Dapaah, *et al.*, 2005). Post-flowering insect pests can be controlled by applying endosulphan (thiodan, Thionex) or dimethoate (Perfekthion, Roxion). Endosulphan is preferred to dimethoate because it is effective against a wider range of post-flowering pests. Where available, Cymethoate, a combination of synthetic pyrethroid and dimethoate can be used for controlling all the insect pests. To control pod-sucking bugs application of a mixture of synthetic pyrethroid and Dimethoate was recommended (Adu-Dapaah *et al.*, 2005. Ghana / CIDA Grain Development Project (1988) and Adu-Dapaah *et al.* (2005) asserted that Actellic (pirimiphos-methyl), Elocron (dioxacarb) and Unden (a carbonate) are not effective in controlling cowpea field pests. Adu-Dapaah *et al.* (2005) further stated that Dursban (chlorpyriphos), Nogos (DDVP, dichlorvos) and sumithion (Fenitrothion) are also not effective in controlling cowpea field pests. Kocide (a fungicide) is not an insecticide; therefore it should not be used against insects. Meanwhile such chemicals were those stated by both farmers and Extension Officers. In some cases even though the chemicals stated by respondents were the recommended ones, the spellings of the names were wrong making it difficult for one to know exactly what chemical was being mentioned. Adu-Dapaah *et al.* (2005) observed that the use of the wrong insecticide will result in little or no insect control. This may rather aggravate the insect pest problem and can also cause contamination of the cowpea. Hence, it can be said that it is not safe for farmers to be using such wrong chemicals. This again calls for thorough training for our Agricultural Extension Officers and intensive education programmes for our farmers on the correct chemicals to be used in controlling cowpea field pests.

Survey and field experiments

Both the survey and field experiment results revealed almost the same type of insects observed on the cowpea flowers. Though most often observed on the petals, thrips and beetles were also observed quite a number of times on the stigma and inside the flowers. *Xylocopa calens*, *Megachile* and *Ceratina* sp. were most often observed on the tip of the stigma. Asiwe (2009) observed butterflies (Lepidoptera), moths (Lepidoptera), *Mylabris* spp., *Oothecca mutabilis* Sahlberg, dragonflies (Odonata), cotton stainer (*Dysdercus suturellus* Herrich Schäffer) and *Medythia quaterna* Fairmaire on cowpea flowers. However, these insects were not associated with pollen movement. On the other hand Asiwe (2009) observed that carpenter bees (*Xylocopa virginica* L.), Digger bees (*An'hophora occidentalis* Cresson), Honey bees (*Apis mellifera* L.), Bumble bees (*Bombus grieocollis* De Geer and *Bombus pennyslvanicus* De Geer), Leaf-cutting bees (*Megachile latimanus* Say) were associated with pollen movement. Adler and Irwin (2006) working on multiple floral visitors observed that *Xylocopa*, *Osmia* and *Habropoda* carried the most *Gelsemium sempervirens* (Loganiaceae) pollen, followed by *Bombus* and *Apis*. They further observed that *Xylocopa* visited flowers through the corolla opening rather than robbing. In this study also pollen grains were observed on the legs and body surfaces of *Xylocopa* spp, *Melecta* sp., and *Apis mellifera*. Hence, these insects may likely cause pollination of the cowpea flowers if they had dropped pollen grains on the stigmas. Since bees and thrips were most often observed on the flowers then it can be said that bees and thrips are very much associated with cowpea flowers from the experimental areas. Since *Xylocopa* sp were very active during the major season but not in the minor season and *Megachile* sp. very active in the minor season but not in the major season then it is possible that there may be some conditions favouring the availability and activities of the two species during the various seasons. These conditions may need to be studied in subsequent works.

Ceratina was most often observed excavating the flowers and appeared to be feeding on the pollen grains. This behaviour portrayed *Ceratina* more as cowpea flower eater than a pollinator.

During the major rainy season, numerous spotted beetles were observed on every part of many of the cowpea flowers. These spotted beetles observed in abundance on the cowpea flowers were mostly found feeding on the cowpea flowers. It so happened that the beetles could eat all the flowers including the flower stalk. Hence, the beetles can be described as cowpea flower eaters. Therefore *Ceratina* sp. and the beetles can be described as cowpea flower pests than pollinators.

The flowers of *Phaseolus vulgaris* L. are entirely self-pollinated. However, they can be cross-pollinated by bees, though, the percentage of cross-pollination is not great (Taylor, 1919). Meanwhile, Mackie and Smith (1935) and Barrons (1939) believed that cross-pollination of *Phaseolus vulgaris* L may amount to more than eight per cent. In this study, during the major rainy season a total fruit set of 284 (61.7%) was recorded. Out of the total successful fruit set, 20.1%, 19.4% and 19.4% were recorded for flowers not visited by any organism and flowers visited by *X. calens* and thrips respectively. The results thus showed a very close percentage fruit set between unexposed flowers and the two most promising insect namely, *X. calens* and thrips which visited flowers in the major rainy season. These findings suggest that both self-pollination and cross-pollination might have taken place. Cowpea is cleistogamous, producing viable pollen and receptive stigma before anthesis. This phenomenon imposes entirely self-pollination on the crop (Asiwe, 2009). However, outcrossing mediated by insects occur in nature (Asiwe, 2009). Vaz *et al.* (2007) asserted that over several years, the mean productivity of cowpea in the Amazon has declined. This might be linked to a decrease in or an absence of pollinating insects in the fields. This submission also suggests that pollinators can boost higher yields in cowpea. In this study, out of the 44.0% successful pod development in the major rainy season, flowers visited by *X. calens* recorded 28.0%, unexposed or control flowers 25.60% and flowers visited by thrips 12.0%. Fruit abortion rate was highest for thrips (14.1%) followed by unexposed flowers (8.8%), *X. calens* (7.1%), *Apis mellifera adansoni* and *X. imitator* (5.3% each). Therefore the results of this research suggest that flowers visited by *X. calens* showed slightly higher pod formation than unexposed flowers and flowers visited by thrips during the major rainy season. It further shows that though unexposed flowers (self-pollinated flowers) recorded the highest fruit set, it also recorded very high rate of fruit abortion (did not develop into pods). The same story can be told about flowers visited by thrips. The results confirm the idea of cowpea undergoing both self- and cross-pollination. This is further buttressed by the statement of Vaz *et al.* (2007) that although cowpea is autogamous, it has a cross-pollination rate of 10%. Agriculture and consumer Protection (Internet– http://www.fao.org/docrep/006/y5110e/y5110e03.htm) also made similar observation that crops vary in the extent to which they benefit from insect cross-pollination. Some crops such as field beans and mangoes are self-pollinating but can give better yields if pollinated by insects. The findings also agreed with the assertion that plants such as passion fruit, cowpea, sesame, litchi, mustard and cashew give a substantially increased yield when pollinated by insects (Agriculture and Consumer Protection (Internet - http://www.fao.org/docrep/006/ y5110e/y5110e03.htm).

In cowpea, premature flower drops and bud abortion are greatest when the plant nears maturation, when the two gametes are incompatible, and when temperatures are high and humidity is low (IITA, Internet- http://www.iita.org/cms/ details/trn_mat/irg42/irg421.htm). Since both unexposed flowers and flowers visited by *X. calens* under this study were all exposed to the same environmental conditions the differences in fruit abortion may not be attributed to temperature or humidity. The only factor that can be considered here is compatibility of the gametes. Even here, since the plants were of the same variety and sown on the same day and both flowers visited by *X. calens* and unexposed flowers were all randomly mixed up on the field the contributing factor towards differences in fruit abortion may be self- and cross-pollination. Here, since the unexposed flowers and flowers visited by other insects had more of their fruits formed aborting than fruits formed from flowers visited by *X, calens* it can be said that *X. calens* might have caused pollination of the flowers that it visited leading to improvement of fruit retention and thereby preventing high fruit abortion.

Though the flower thrips *Megalurothrips sjostedti* (Trybom) is considered as one of the most destructive pests attacking the reproductive structures of cowpea during plant development (Tamo *et al.*, 1993), it appears from this study in the major rainy season that in some cases fruit set and pod formation can still take place even when the thrips affect the flowers. Mackie and Smith (1935) and Allard (1954) credited thrips for cross-pollination in *Phaseolus lunatus* L. (Lima beans). The finding of this study is in line with the views of Mackie and Smith (1935) and Allard (1954) suggesting that thrips could cause cross-pollination. It further goes to support the point made by Mackie and Smith (1935) that thrips were responsible for 0.7% outcrossing observed in common beans. In the minor rainy season, flowers visited by *Megachile* sp. recorded a higher fruit set (36.7%) than unexposed flowers (26.7% fruit set). Here also it appears that *Megachile* sp promised to be a pollination agent of cowpea flowers because the flowers visited by *Megachile* sp. formed more fruits than the unexposed or control flowers.

Abrol (1997) stated that the most efficient pollinators must carry plenty of pollen on their bodies, brush against stigmas of flowers, transferring the pollen, visit several flowers of the same species in succession and move frequently from flower to flower and plant to plant. These descriptions fit the behaviour of *X. calens* and *Megachile* sp. on the cowpea flowers. It was realized that both *X. calens* and *Megachile* sp. carried a lot of pollen grains on their bodies. Both insects were also found to move very fast from flower to flower. Within one minute, one *X. calens* or *Megachile* sp. visited between 6 to 8 flowers. When on the flower, they inserted their tongues down the ovary and their bodies brushed against the tip of the stigma of the flowers. These characteristics of *Xylocopa calens* and *Megachile* sp. put them in favourable positions to cause pollination in cowpea. However, there is the need to undertake another study using a technique that will help in finding out whether pollen grains deposited on the stigmas of flowers visited by the insects are actually deposited there by the insects and if such pollen grains are from flowers of other cowpea plants.

In this study, during the major rainy season, there was no clear cut relationship between fruit formation and any of the weather conditions (rainfall, temperature and relative humidity). However, during the minor rainy season, it appears that as rainfall increased, fruit formation for unexposed flowers also increased. However, the opposite relationship was observed for temperature. Here it was observed that as temperature increased fruit formation for the unexposed flowers decreased. The finding here is suggesting that as rainfall increases and temperature reduces unexposed or self-pollinated cowpea flowers may easily form fruits. However, if rainfall increases and temperature also increases then there will be reduced fruit formation for the unexposed flowers. The findings here appear to be confirming the findings of Ahmed *et al.* (1992) that in cowpea high night temperatures during floral development induce male sterility. They asserted that when plants were grown under controlled temperatures in both greenhouses and growth chambers in separate experiments, floral development was normal under a night temperature of 20°C, whereas when flowers developed under high night temperature (30°C) there was no fruit set and pod development due to low pollen viability and anther indehiscence (Ahmed *et al.*, 1992). Therefore, it is possible that when temperatures were high the pollen grains of the unexposed cowpea flowers might have become sterile thereby leading to no pollination and hence no fruit formation. It is hereby suggested that more work is done to monitor the relationship between weather conditions and fruit formation in cowpea over a longer period of time where fruit set will depend on changes in the weather conditions. Here also, fruit set for unexposed (self-pollinated) and flowers exposed to insects should be studied to find out if weather conditions influence fruit formation in any way in each case. The results of that study will help to explain how cowpea fruit formation differs with changes in weather conditions when self-pollination and cross-pollination by insects take place.

The findings seem to be confirming the assertion by Abrol (1997) that cross-pollination improves the quantity of fruits. This is because in the major rainy season flowers visited by *X. calens* formed more fruits than unexposed flowers and flowers visited by thrips respectively. Similarly, during the minor rainy season the total number of pods developed from flowers visited by *Megachile* sp. was more (46.1%) than that from unexposed flowers (32.9%). Here the percentage failure for pod development was higher for flowers visited by *Megachile* sp than unexposed flowers. This was as a result of higher fruit set rate for flowers visited by *Megachile* sp. than unexposed flowers. This result confirms the findings of Warnock and Hagedorn (1954) that frequent visitation by pollinating insects to blossoms of cowpeas is beneficial in increasing the number of pod set.

Sen and Bhowal (1962) reported the development of a male-sterile mutant cowpea. They went on to say that it has not been utilized in hybrid seed production, but if such a mutant were used, since cowpeas are not wind pollinated, insects large enough to operate the floral mechanism would be required to carry pollen from fertile to male-sterile plants. In this study, results are suggesting that large bees such as *X calens* and *Megachile* sp. are the promising cowpea pollinators from the research area.

According to Emechebe and Shoyinka (1985), viruses, web blight, *Cercospora*, brown blotch, Septoria and Scab in the moist savanna and bacterial blight, false smut and ashy stem blight in the dry savanna are some of the major diseases that affect cowpea plant growth and biomass production and affect the quality of both grains and fodder (Emechebe and Shoyinka, 1985). In this study, during the major rainy season, majority of the pods developed became mouldy, withered and later fell off as a result of withering of the plants. This might probably be due to soil borne disease.

During the major rainy season, 28.5% of flowers visited by *X. calens* developed between 7 to 12 seeds per pod whilst 16.3% of the unexposed flowers developed between 4 to 6 seeds per pod. This result suggests that more seeds per pod are produced when *X. calens* visits the cowpea flowers. This may be as a result of cross-pollination. Also, in the minor rainy season, the total number of seeds formed in pods developed from flowers visited by *Megachile* sp. (224) was more than that developed from unexposed flowers (170). Here 38% of the flowers visited by *Megachile* sp. developed between 7 and 12 seeds per pod whilst 34% of the unexposed flowers developed between 4 and 9 seeds per pod. Here also it can be said that flowers visited by *Megachile* sp. produced pods with higher number of seeds than the unexposed flowers. This may also be due to cross-pollination by *Megachile* sp. For seed length, looking at 0.9 – 1.1cm and 1.2+cm, it is clear that there is no clear cut difference. Similarly, there is no clear cut difference between the seed circumference for flowers visited by *Megachile* sp. and unexposed flowers.

Progenies of seeds obtained from the minor rainy season– morphological studies of progenies

According to McGregor (Internet- http://maarec.cas.psu.edu/bkCD/Pollination /pollofcrops.html) the value of hybrid seed is not reflected until the next generation. Vigor of sprouting and emerging from the soil is often a vital factor in the plant's early survival. Other responses to hybrid vigor include earliness of development, plant health, and greater and more uniform production of fruit or seed. In this study the progenies of flowers visited by *Megachile sp.* started producing flowers two days earlier than the progenies of unexposed flowers. Though, the number of days difference can be considered as insignificant it is important to say that *Megachile* might have caused pollination which imposed earlier flowering and fruiting on its progenies. This finding confirmed similar observation of Free (1966) which showed that if growers of Scarlet runner beans (*Phaseolus coccineus* L.) want to obtain maximum yields and harvest the seeds as early as possible, then they should have a high pollinator population in the field, particularly during early flowering. FAO Corporate Document Repository (Internet- http://www.fao.org/docrep/006/ y110e /y5110e03.htm) also stated that adequate pollination by insects ensures that early flowers set seeds. This results in a uniform and early harvest and gives the crop the maximum length of time to ripen. However, a further study is recommended to find out if progenies of flowers visited by *Megachile* sp. can flower much earlier than the progenies of the unexposed (control) flowers.

The results showed that the leaves of the progenies of control (unexposed) flowers were far larger than leaves of the progenies of flowers visited by *Megachile* sp. It was realized that for the progenies of flowers visited by *Megachile* sp. the least mean leaf area was 4.1 cm^2 and the largest value was 6.9cm^2. In the case of the progenies of unexposed flowers the least mean leaf area was 16.7cm^2 and the largest was 21.2 cm^2. It can be argued here that the differences in the leaf area are probably due to characteristics that were embedded in the seeds that were sown. Further it can be argued that the characteristics might be due to self- and cross-pollination where the cross-pollination was believed to have been caused by *Megachile* on visiting cowpea flowers. Hence, these characteristics might be transferred into the seeds that were formed and that the characteristic as a result of cross-pollination makes cowpea leaves very small. Hence, this might be the reason why all the leaves of the progenies of flowers visited by *Megachile* sp. were smaller than those of the progenies of unexposed flowers. The small leaf area of the progenies of flowers visited by *Megachile* sp. may be an advantage for the plants during dry seasons for the leaves may not lose water easily from their surfaces compared to the big leaves of the progenies of unexposed flowers. However, there is the need for further studies into whether pollination of cowpea by *Megachile* can cause leaves of progenies to be very small and if it does then what are the advantages and disadvantages.

It has been known for a considerable time that changes in chlorophyll fluorescence emission from photosynthetic organisms are frequently indications of changes in photosynthetic activity (McAister and Myers, 1940; Kautsky and Zedllitz, 1941). From the measurement of the ratios of chlorophyll fluorescence emission spectra intensities at 683 and 731 nm, F683 / F 731, and other significant intensity ratios, an increase of the ratio F690 / F740 is caused by a lower chlorophyll content and / or decline in photosynthesis (Karlson, 1992). From the results of this study the calculated fluorescence decrease ratios (Rfd) for the progenies of unexposed flowers was 0.9 whilst that of the progenies of flowers visited by *Megachile* sp. was 0.8. The Rfd levels show that the leaves of the progenies of unexposed flowers were more photosynthetically efficient than those of the progenies of flowers visited by *Megachile* sp. Meanwhile, an observation of the leaves showed that leaves of the progenies of flowers visited by *Megachile* sp. were far greener than leaves of the progenies of unexposed flowers. Therefore, it was thought that the leaves of the progenies of flowers visited by *Megachile* sp. were having more chlorophyll (green pigment) than leaves of the progenies of unexposed flowers. If that had been true then a corresponding better photosynthetic activities of leaves of the progenies of flowers visited by *Megachile* sp. was expected. However, this has not been the case making the results here very difficult to explain.

Meanwhile it is known that chlorophyll fluorescence ratio F690 / F735 is much increased with decreasing chlorophyll content and also enhanced though to a lower degree with a loss of photosynthetic function (Rinderle and Lichtenthaler, 1988). Here, it can be stated that the leaves of the progenies of flowers visited by *Megachile* sp. might have looked greener than leaves of the progenies of unexposed flowers because the leaves of the progenies of flowers visited by *Megachile* sp. were smaller and concentrated the little chlorophyll that they contained while the leaves of the progenies of unexposed flowers contained much more chlorophyll, the chlorophyll is spread in the large leaves making the leaves to look less green. Therefore, that might be the reason why the leaves of the progenies of the unexposed flowers were more photosythetically efficient than the leaves of the progenies of flowers visited by *Megachile* sp.

Baker and Rosenqvist (2004) indicated that environmental stress factors can impact indirectly on fluorescence induction characteristics by perturbing metabolic pools associated with photosynthetic metabolism. Therefore, reduced rate of photosynthesis can induce a reduced rate of growth in plants without inducing damage to the plant (Lichtenthaler, 1988). Hence, the lower photosynthetic rate in the leaves of the progenies of flowers visited by *Megachile* sp. may also be attributed to a factor induced by cross-pollination caused by *Megachile* which works with environmental stress factors to impede efficient photosynthesis. This assertion can be buttressed by the observation of Lichtenthaler (1988) that the ratio F690/F735 is a very suitable stress indicator in green plants and possibly also in remote sensing. In general, stress conditions are caused by factors such as high temperatures, water supply, light intensity, mineral contents of the soil and genetic factors (Lichtenthaler, 1988). Under stress conditions, for example water stress and desiccations, the fluorescence decrease (fd) from the maximum (fmax) to the steady state becomes increasingly lower and the steady state fluorescence (fs) continuously rises (Lichtenthaler, 1988). Since all the above submissions are negative then it can be said that if *Megachile* pollination is causing any of the discussed stress situations then *Megachile* pollination becomes a disadvantage to photosynthesis in cowpea than an advantage. However, it is very difficult to prove any of the points advanced here under the current studies. This calls for further studies to find out if actually *Megachile* visiting cowpea flowers can induce any stress factors in the leaves of the progenies leading to reduced photosynthesis.

In this study the results showed that generally, the progenies of flowers visited by *Megachile* sp. developed more flowers than progenies of unexposed flowers. Similarly, the progenies of flowers visited by *Megachile* sp. formed more pods than the progenies of unexposed flowers. The sequence repeated itself where there was a higher level of fruit abortion for the progenies of flowers visited by *Megachile* sp. than progenies of unexposed flowers. Since progenies of flowers visited by *Megachile* sp. formed more flowers than the progenies of unexposed flowers it was also expected that the progenies of flowers visited by *Megachile* sp. would form more pods than progenies of unexposed flowers. Similar results were obtained by Gomez (2000) in a study on *Lobularia maritima*, where it was found out that inflorescences pollinated by ants produced more flowers than those pollinated by winged insects. It was also found out that pollinator exclusion affected fruit set such that plants pollinated by ants showed higher values of fruit set than any other treatment. Flowers from which all pollinators were excluded produced significantly fewer seeds than those visited by ants and winged insects (Gomez, 2000).

Though the differences were not significant, the weekly fruit abortion rate shows that more fruit abortion occurred for progenies of flowers visited by *Megachile* sp. than those of the progenies of unexposed flowers. Here, it is not surprising because generally, the progenies of flowers visited by *Megachile* sp. formed more fruits than progenies of the unexposed flowers. This is necessary because if all the fruits remain on the plant they may not produce very large pods and seeds. This is because the food that is absorbed by the plant would have been distributed to all the fruits for growth and development.

The effectiveness of a flower visitor as a pollinator is ultimately quantified as its contribution to plant fitness (Herrera, 1989; Kearns and Inouye, 1993; Fishbein and Venable, 1996; Waser *et al.*, 1996; Traveset and Saez, 1997). Drayner (1956, 1959), Bond and Fyfe (1962) also showed that continued inbreeding of field beans causes a progressive loss in the ability of the plant to develop seeds, but upon hybridization (cross-pollination) this ability is restored. The implication is that the plant can survive several generations, but not indefinitely without cross-pollination although production continually decreases. The results of this study showed that the number of seeds per pod ranged between 4 and 15. In both cases many pods bore seeds ranging between 10 and 12. However, the progenies of flowers visited by *Megachile* sp. developed a higher number of pods (33.5% of pods) bearing seeds ranging from 10 to 12 compared to progenies of unexposed flowers (25.3% of pods). This suggests that when *Megachile* visits cowpea flowers the progenies produced may develop pods with many more seeds than pods developed from progenies of control. This may be due to *Megachile* causing pollination of the flowers visited.

Similarly, progenies of flowers visited by *Megachile* sp. developed more pods (13.0% of pods) with 13 to 15 seeds than progenies of unexposed flowers (8.5%) (Table 22). This also suggests *Megachile* pollination of the flowers leading to production of more seeds per pod in the progenies produced. In all, progenies of the flowers visited by *Megachile* sp. recorded higher number of seeds out of 70 pods than progenies of unexposed flowers. The results therefore showed that the pods developed by the progenies of flowers visited by *Megachile* sp. produced more seeds than the progenies of unexposed flowers. In this case also cross-pollination attributed to *Megachile* may be responsible.

Anderson *et al.* (2004) asserted that the number of seeds produced by a plant depends on the photosynthetic capacity of the plants. Plants with high photosynthetic capacity tend to produce more seeds per pod, and give higher seed yield (Anderson *et al.*, 2004). The findings of this study appear to be at variance with the assertions of Anderson *et al.* (2004). In this study the results of chlorophyll fluorescence induction kinetic (discussed earlier on) showed that the leaves of the progenies of flowers visited by *Megachile* sp. were less photosynthetically efficient compared to the leaves of the progenies of unexposed flowers. However, the pods of the progenies of flowers visited by *Megachile* sp. produced more seeds compared to the pods of the progenies of unexposed flowers. Therefore, in this study since the progenies of flowers visited by *Megachile* sp. showed the production of more flowers, pods and seeds than the progenies of unexposed flowers, though the progenies of the unexposed flowers were better in undertaking photosynthesis, it will be difficult to say that plants with high photosynthetic capacity tend to produce more seeds per pod, and give higher seed yield. The findings are further suggesting that despite lower photosynthetic rate for the progenies of flowers visited by *Megachile* sp, cross-pollination by *Megachile* sp. might have contributed a factor deposited in the flowers that formed the seeds which were sown leading to production of more seeds in its progenies than the progenies of unexposed flowers.

Seed size is an important yield component in cowpea production (Anderson *et al.*, 2004). The results of this study showed that the progenies of seeds obtained from flowers visited by *Megachile* sp. developed longer seeds than the progenies of unexposed flowers. Also, progenies of flowers visited by *Megachile* sp. developed seeds with bigger circumference than progenies of unexposed flowers. These suggest that the progenies of flowers visited by *Megachile* sp. formed seeds which are bigger than progenies of unexposed flowers. This may likely be due to cross-pollination caused by the *Megachile* sp which induced the visited flowers with better characteristics for bigger cowpea grains in their progenies. These finding seem to conform to the observation by FAO Corporate Document Repository (Internet-http://www.fao.org/docrep/006/y110e/y5110e03.htm) that insect pollination affects both the quantity and quality of crops; uneven small fruit often indicate insufficient pollination.

If pollinators differing in foraging pattern visit self-compatible plants, their differential effect on host plant fitness would mainly appear in later, post-dispersal life cycle stages, causing the host plant to produce low-quality seeds after pollination (Snow *et al.*, 1996). In the current study under discussion, results of nutrient analysis showed that progenies of seeds obtained from unexposed flowers generally contained higher levels of starch than progenies of flowers visited by *Megachile* sp. Photosynthesis produces carbohydrates. No doubt chlorophyll fluorescence induction kinetics (discussed earlier on) showed that photosynthesis was more efficient in the progenies of unexposed flowers than the progenies of flowers visited by *Megachile* sp. However, progenies of flowers visited by *Megachile* sp. generally contained more calcium and phosphorus than progenies of unexposed flowers. On the other hand the progenies of unexposed flowers recorded higher fibre content levels than progenies of flowers visited by *Megachile* sp. For protein, progenies of flowers visited by *Megachile* sp. recorded higher values than progenies of unexposed flowers. FAO (1988) also observed that cowpea is rich in protein, iron, starch, calcium, phosphorus and vitamin B which make it excellent food when eaten even in small amounts. Also in studies of 32 cowpea accessions for variation in content of protein and mineral nutrients (Calcium, magnesium, potassium, and sodium) Asante *et al.* (2006) reported that protein content ranged between 16.35 and 27.27%; sodium content ranged between 90.5 to 91.3 ppm, and potassium content from 30.33 to 71.3 ppm. Asante *et al.* (2006) further reported values of magnesium and calcium as 146 .7 to 968.2 ppm and 43.3 to 171.2 ppm respectively. They also reported that percentage crude protein correlated significantly positively with sodium and negatively with calcium. Magnesium also correlated significantly with potassium. Black seeds generally recorded the highest percentage crude protein on the average, whilst cream seeds had the highest magnesium and calcium contents respectively (Asante *et al.*, 2006). In this study, the differences may be attributed to self- and cross-pollination in which the cross-pollination might be caused by *Megachile*. These are further suggestive of the fact that cross-pollination by Megachile may produce cowpea plants whose offspring may in turn produce seeds with high protein and low fibre content.

Carbohydrates are the main sources of energy in the body (Ramalingam, 1993; Taylor *et al.*, 1997 and Mackean, 1985). Hence, the seeds of the progenies of unexposed flowers would be better sources of energy than seeds produced from the progenies of flowers visited by *Megachile* sp. Calcium and phosphorus are also needed by the body for the formation of healthy teeth and bones (Ramalingam, 1993; Samuel *et al.*, 1989). Ramalingam (1993) and Samuel *et al.* (1989) further stated that calcium is also needed by the body for the proper functioning of the heart and nervous system, normal contraction of the muscles and clotting of blood. Therefore the results suggest that consumption of the seeds of the progenies of flowers visited by *Megachile* sp. may help the body in carrying out these functions more effectively than when seeds of progenies of unexposed flowers are consumed. It presupposes that the consumption of the seeds of the progenies of unexposed flowers will better stimulate the movement of food through the gut and thereby help to reduce blood cholesterol levels in the body and the risk of bowel cancer and gall stones (Taylor *et al.*,1997) than seeds of the progenies of flowers visited by *Megachile* sp. This is because the seeds of the progenies of unexposed flowers contained more fibre than the seeds of the progenies of flowers visited by *Megachile* sp.

Dovlo *et al.* (1976) observed that cowpea (*Vigna unguiculata* (L.) Walp) is a source of relatively low cost, high quality protein. Marconi *et al.* (1990) also stated that the cultivated cowpea (*Vigna unguiculata* (L.) Walp) is the most important source of plant protein in the human diet in tropical Africa particularly in the Sahel region. Protein is very essential for growth, the repair and replacement of worn out cells in the body (Samuel *et al.*, 1989; Ramalingam, 1993; Taylor *et al.*, 1997). They are also essential in the formation of enzymes and hormones (Ramalingam, 1993) and can also be used as a source of energy if the diet is deficient of carbohydrates and fat (Taylor *et al.*, 1997). Therefore, it can be said that the seeds of the progenies of flowers visited by *Megachile* sp. can be very useful and better sources of protein than seeds of the progenies of unexposed flowers. It can further be said that it may not be too much of worry when the seeds of the progenies of flowers visited by *Megachile* sp. are not containing high levels of starch (carbohydrates) because protein can be converted into carbohydrates to fix energy for the body in the absence of the carbohydrate (Taylor *et al.*, 1997).

In this research the roots of the progenies of flowers visited by *Megachile* sp. developed higher number of nodules than the progenies of unexposed flowers. Again the differences can be attributed to self- and cross-pollination. Thus, it is conceived that *Megachile* caused cross-pollination of the flowers it visited. This therefore is further suggesting that when cross-pollination occurs in cowpea flowers it may leave the flower with characteristics that can favour the production of a higher number of nodules in the offspring produced. Meanwhile it is known that the cowpea has the ability to fix atmospheric nitrogen into the soil in symbiosis with the rhizobium bacteria species (Purseglove, 1968). This was further confirmed by Ayanaba (1979) and Doku (1970) that among tropical grain legumes, cowpea has high nitrogen fixation ability, which ranges from 70-350kg/ha of nitrogen. It is also known that the members of the genus *Rhizobium* possess the ability to survive and multiply in soil and to compete in nodule formation (Brockwell *et al.*, 1968; Franco and Vincent 1976; Date and Roughley, 1977; Date and Brockwell, 1978). According to Joseph *et al.* (1985) the reduction in the number of cowpea rhizobia in soil was found to be associated with the reduction in the number of nodules per plant. A number of scientific studies have shown that cowpea nodulation in tropical soils could not be improved by supplying in larger number selected nitrogen fixing bacteria strains with high symbiotic performance (Gueye, 1983, Awonake *et al.*, 1990). Therefore, the production of large numbers of nodules by the roots of the progenies of flowers visited by *Megachile* sp. may be advantageous because the plants may be able to fix much nitrogen in the soil thereby improving soil fertility for the cultivation of other crops. Hence, cross-pollination of cowpea by *Megachile* may improve nodule formation on the roots of the offspring.

CHAPTER SIX

SUMMARY OF FINDINGS, CONCLUSIONS AND RECOMMENDATIONS

Summary of findings

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors and the effects of pesticide control measures on them

1. In this study majority of the farmers (80.8%) and Agricultural Extension Officers (86.4) were males.

2. The farmers were mainly between 15 and 55 years old whilst majority of the Agricultural Extension Officers were between 26 and 45 years old

3. About education, 43.3% of the farmers attended secondary school. For the extension officers 81.8% obtained Certificate in Agriculture

4. For experience, 71.2% of the farmers have been cultivating cowpea for between 1 and 5 years whereas 40.90% of the Extension Officers have been providing extension services for 6-15 years.

5. Also, 48.1% of the farmers do less than 1 acre a year whilst 38.5% do 6-10 acres per year.

6. Also, 45.5% of the Extension Officers asserted that they have 1-20 farmers under them.

7. A high percentage of cowpea farmers (98.0%) and all the Extension Officers had knowledge of pollinators.

8. Most farmers (98.1%) and 88.6% of Extension Officers stated that pollinators transfer pollen grains from the anther to the stigma. However, 2.9% of the farmers and 11.4% of the Extension Officers were of the opinion that pollinators destroy flowers.

9. Concerning the level of knowledge of pollinators, 42.3% of the farmers rated themselves less than 40% whilst 36.5% rated themselves 40-50%. For Extension Officers also 36.4% rated themselves 51- 60%, 31.8% rated themselves 40 – 50% and 13.6% rated themselves less than 40%.

10. All the Extension Officers and 96.2% (100) of the farmers agreed that farmers need some training in the knowledge of pollinators and their usefulness.

11. The results showed that 50% of the farmers agreed that lepidopterans do visit the flowers while all the other insects have been rejected by majority of the farmers as insects that visit the cowpea flowers. However, majority of the Extension Officers agreed on bees and Lepidopterans as the insects that visit the cowpea flowers. They generally rejected all the other insects.

12. Majority of the farmers agreed that cross-pollination leads to increased fruit set/increased crop yield while they rejected all the other points. Similarly, increased fruit set/increased crop yield and increased fruit viability were popular with the extension officers while they generally rejected all the other points presented to them

13. Pesticide application was considered as one of the most harmful practices against flower visitors/pollinators by both farmers and Extension Officers.

14. Generally, 59.6% and 67.3% of farmers considered bees and lepidopterans respectively as pollinators whilst 63.5%, 46.2% and 34.6% of them considered beetles (Coleopterans), ants and flies (Dipterans) respectively as pests. Also, 90.9% and 68.2% of Extension Officers considered bees and Lepidopterans respectively as

pollinators whilst 54.6% and 68.2% of them considered thrips and flies respectively as pests.

15. On what is done when pests infest the crops, 90.4% of farmers and 81.8 % of Extension Officers intimated that the crops are sprayed with chemicals. Out of the 94 farmers who agreed on chemical applications, 50.0% and 32.0% stated that chemicals are sprayed twice and once respectively during a cropping period. On the other hand 52.8% and 30.6% of Extension Officers indicated that chemicals are sprayed once and twice respectively.

16. From the results cowpea farmers agreed that the cowpea plants are sprayed during flowering stage, but extension officers agreed on before flowering and at fruiting stages.

17. Concerning the effects of chemicals on insect pollinators, 57.7% of the farmers indicated that they did not know while all the Extension Officers agreed that chemicals can kill insect pollinators.

18. While 55.3% of the farmers agreed that other insects apart from pests are killed by chemicals, all the Extension Officers indicated that only the pests are killed.

19. In all, 53.9 % of the farmers and all the Extension Officers agreed that agricultural officers advise farmers on chemical control measures.

20. Farmers who indicated that agricultural officers advise them on chemical control measures could not generally agree on any specific topic on which the training is centered whilst all the Extension Officers agreed on all the topics presented to them

21. Also, apart from chemical control, farmers could not generally agree on any other pest control measures whilst the officers agreed that none of the methods stated were available to the farmers.

22. The chemicals stated by both cowpea farmers and extension officers as those that are used in controlling cowpea pests include both wrong and banned chemicals.

Survey and field experiments

23. Thrips (Thripidae) were the insects most often observed on the cowpea flowers in the surveyed farms followed by flies (Dipterans), *Lasioglossum* sp (Halicitidae: Halicitinae) and Lepidopterans (butterflies and moths). Other insects observed on the flowers during the survey were bees such as: *Apis mellifera adansoni* (Apidae), *Ceratina* sp (Apidae: Xylocopinae), *Megachile* sp (Megachilidae: Megachilinae), and *Xylocopa* sp (Apidae: Xylocopinae), crickets (Orthoptera), ants (Hymenoptera), beetles (Coleoptera) and wasps (Hymenoptera).

24. The most frequently observed insects on flowers in the experimental farm during the major rainy season were thrips followed by beetles (Spotted), *Xylocopa calens*, *Ceratina* sp, Lepidoptera, flies and *Xylocopa imitator*.

25. The main insects observed on the cowpea flowers during the minor rainy season were bees such as Apis *mellifera adansoni, Ceratina sp, Megachile sp.*, and *Lasioglossum* sp.; and other insects such as thrips, flies and Lepidoptera.

26 During the minor rainy season the most active insect on the tip of stigmas of the flowers was *Megachile* sp whilst thrips, Lepidoptera, *Lasioglossum* sp and flies were very active on the petals of the flowers.

27. In the major rainy season, a total fruit set of 284 (61.7%) and fruit set failure of 176 (38.3%) were recorded. The successful fruit set results were, 20.1%, 19.4% and 19.4% for unexposed (Control) flowers, flowers visited by *X. calens* and thrips respectively

28. From the total fruit set of 284, 12.3% and 11.3% pod development were recorded for flowers visited by *X. calens* and unexposed flowers respectively.

29. Fruit abortion rate was highest for flowers visited by thrips (14.1%), followed by the unexposed flowers (8.8%), flowers visited by *X. calens* (7.0%), *Apis mellifera* and *X. imitator* (5.3%) respectively.

30. During the minor rainy season, flowers visited by *Megachile* sp. recorded higher fruit set (36.7%) and higher pod development (46.1%) than the unexposed flowers (26.7% fruit formation and 32.9% pod development)

31. In the major rainy season, out of 80 pods, 32.5% developed from flowers visited by *X. calens*, 27.5% from unexposed flowers and 16.3% from flowers visited by *Ceratina* sp. In all, 16.3% and 12.3% pods that developed from flowers visited by *X. calens* had 7 – 9 and 10 – 12 seeds per pod respectively. For the unexposed flowers also, 13 (16.3%) pods had between 4 – 6 seeds per pod.

32. During the minor rainy season, the total number of seeds formed in pods developed from flowers visited by *Megachile* sp. was 224 and that for the unexposed flowers 170. For *Megachile* sp. 20% and 18% of the pods developed 10 – 12 and 7 – 9 seeds per pod respectively. On the other hand for the unexposed flowers, 14% and 20% of the pods developed 7 –9 and 4 – 6 seeds per pod respectively.

33. Also during the minor rainy season, 40.9% and 26.1% of the seeds were of circumference 1.6 – 2.0 cm for flowers visited by *Megachile* and those not exposed respectively.

Experiment with seeds from experimental farm during the minor rainy season – morphological studies of progenies

34. For the progenies of flowers visited by *Megachile* sp the least average leaf surface area was 4.1 cm^2 and the largest mean value was 6.9 cm^2. In the case of the progenies of unexposed (control) flowers the least average leaf surface area was 16.7cm^2 and the largest was 21.2 cm^2.

35. The calculated fluorescence decrease ratio (Rfd) for the progenies of unexposed flowers was 0.9 whilst that of progenies of flowers visited by *Megachile* sp. was 0.8.

36. The results also showed that in all cases the highest average number of flowers for the progenies of both unexposed flowers (234.0) and progenies of flowers visited by *Megachile* sp. (311.5) were recorded during the fourth week of sampling.

37. The progenies of unexposed flowers developed a total of 2163 pods while the progenies of flowers that were visited by *Megachile* sp.developed a total of 2986 pods.

38. The progenies of flowers visited by *Megachile* sp.developed a higher number of pods (201 pods) bearing seeds ranging from 10 to 12 compared to progenies of unexposed flowers (151 pods). Similarly, progenies of flowers visited by *Megachile* sp. developed more pods (78 pods) with 13 to 15 seeds per pod than the progenies of unexposed flowers (51 pods)

39. For the progenies of unexposed flowers, a total of 3839 seeds were obtained out of 70 pods while a total of 4406 seeds were obtained out of 70 pods for the progenies of flowers visited by *Megachile* sp.

40. Also, the progenies of flowers visited by *Megachile* sp. developed longer seeds than the progenies of unexposed flowers. Similarly, the progenies of flowers visited

by *Megachile* sp. developed seeds with bigger circumference than progenies of unexposed flowers.

41. For seed Phosphorus content, seeds obtained from the progenies of unexposed flowers recorded the highest value of 5.5 mg/kg and 6.2 mg/kg for seeds obtained from the progenies of flowers visited by *Megachile* sp. The highest fibre content for seeds obtained from the progenies of unexposed flowers was 29.6 mg/kg and that of the seeds obtained from the progenies of flowers visited by *Megachile* sp. was 26.3 mg/kg. Finally, the highest protein content for seeds obtained from the progenies of the unexposed flowers was 235.6 mg/kg and that of the seeds obtained from the progenies of flowers visited by *Megachile* sp. was 253.9 mg/kg.

42. The roots of the progenies of flowers visited by *Megachile* sp. developed higher number of nodules than that of the progenies of the unexposed flowers.

Conclusion

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors within the cowpea agro-ecosystems

The study revealed that more males than females are involved in cowpea farming in the study areas. Also the Agricultural Extension Officers in the three districts were mainly males.

Almost all the farmers had one form or other of formal education. Hence, they may find it a bit easier understanding lessons on pollinators and pest control if they can have the opportunity. However the Extension Officers generally have very low academic backgrounds (General Certificate in Agriculture).

Majority of the farmers have very few years of experience in cowpea farming, On the other hand majority of the Extension Officers have between 6 and 30 years experience in providing extension services. Also, from the findings it can be said that cowpea is mainly cultivated at a subsistent level in the research areas.

It is clear from this study that most of the farmers (98.0%) and all the Extension Officers have some kind of knowledge of pollinators to the extent that they are aware that pollinators can transfer pollen grains from the anther to the stigma of flowers. However, in terms of in-depth knowledge almost all the farmers and some Extension Officers have a very low personal knowledge of pollinators

Both farmers and the Extension Officers did not have much knowledge about the kinds of insects that normally visit the cowpea flowers. Similarly, both cowpea farmers and Extension Officers did not know, or were not sure what exactly the insects presented to them do on the cowpea flowers. Also, apart from increased fruit set / increased crop yield, farmers and Extension Officers did not know of any other benefit of pollination.

Over ninety percent of farmers and all the Agricultural Extension Officers value training for farmers in the knowledge of pollinators and their usefulness. The Extension Officers believed that such training is necessary to help the farmers to know the importance of pollinators and not to destroy them; for farmers to know the difference between pests and pollinators; to help learners to know how to identify pollinators and other useful insects; and to help farmers to know much about pollinators and their usefulness.

The indications are that over eighty percent of the Extension Officers organize the training for the farmers on topics such as insect pest control measures, types of pollination agents, the right time to spray chemicals, right dose of chemicals to spray, and the need to carry beehives to farms during flowering.

Both farmers and Extension Officers agreed that chemicals are sprayed when pests infest the crops. However, the responses of both farmers and Extension Officers clearly showed that they do not know exactly how many times the cowpea plants need to be sprayed before harvest.

It can also be inferred from the results that while most of the Extension Officers know the right times of pesticide application in the cowpea agro-ecosystem, majority of the farmers do not know, suggesting that the Extension Officers might not have been doing much to educate the farmers on issues such as this.

Since pesticide application cannot kill only the insect pests but will definitely kill some of the other insects found on the plants, including the beneficial insects it can be said that the Extension Officers again lack knowledge of the effects of chemicals on insects on the cowpea plants. This is because whilst over half the number of the farmers agreed that apart from pests, other insects are also killed by the chemicals, all the Extension Officers indicated that only the pests are killed. Contrarily, narrowing on pollinators, all the Extension Officers and majority of the cowpea farmers agreed that synthetic chemicals can kill insect pollinators. Another contradiction is that all the Extension Officers generally agreed that none of the insects presented to them in the instrument except wasp could be killed by chemicals applied on the cowpea plants while majority of the farmers agreed on ants, beetles and flies.

The findings revealed disparity in the number of farmers and Extension Officers agreeing to the point that Agricultural Officers do advise the farmers on chemical control measures. Further, it was not easy to tell which of the two groups, farmers or Extension Officers was telling the truth as to whether agricultural officers advise cowpea farmers on chemical control measures.

Generally, farmers do not have any other pest control measures apart from chemical control available to them. Though some of the cowpea farmers and Extension Officers are aware of the right chemicals to apply against cowpea pests, others were not aware and use the wrong chemicals. It seems even the Extension Officers still recommend banned and wrong chemicals to the cowpea farmers to use.

Looking at the overall results on the knowledge of cowpea farmers and Agricultural Extension Officers about cowpea flower visitors, it can be said that while both cowpea farmers and Agricultural Extension Officers up to some extent have the right knowledge of the activities of cowpea insect flower visitors and pollinators as well as the effects of chemical control measures on them, they (farmers and officers) equally lack knowledge in some aspects which raise serious concerns.

Survey and field experiments

Generally, the insects observed on the cowpea flowers were bees (Hymenopterans) such as *Apis mellifera adansoni* (Apidae), *Ceratina* sp (Apidae: Xylocopinae), *Megachile* sp (Megachilidae: Megachilinae), *Xylocopa calens* (Apidae:Xylocopinae), *Xylocopa imitator* (Apidae: Xylocopinae), *Amegilla* sp (Apidae: Anthophorinae), *Brausapis* sp (Halictidae: Halictinae), *Lipotriches* sp., *Lasioglossum* sp (Halictidae: Halictinae), *Lipotriches* sp (Halictidae: Halictinae), *Melecta* sp (Apidae: Apinae), and other insects such as thrips (Thripidae), flies (Dipterans), lepidopterans (butterflies and moths) beetles (Coleopter), *Dysdercus* sp. and wasps (Hymenoptera).

Thrips were the insects most often observed on the cowpea flowers in the surveyed farms followed by flies, *Lasioglossium* sp and lepidopterans. Also, in the major rainy season the insects observed most often on the cowpea flowers in the experimental farm were thrips. However, in the minor rainy season the insect observed most often on the cowpea flowers in the experimental farm was *Megachile* sp. Since bees and thrips were more often observed on the flowers than any other group of insects, then it can be said that bees and thrips are very much associated with cowpea flowers in the research area. The findings further showed that there were significant differences between the frequency of occurrence of various insects on parts of the flower.

Xylocopa calens, *Megachile* and *Ceratina* sp. were the bees most often observed on the tip of the stigma. Since the stigma of a flower is the structure of a flower that receives pollen grains leading to pollination, then it can be said that it is likely that *Xylocopa calens*, *Megachile* and *Ceratina* sp may be pollinators of cowpea flowers if they had dropped pollen grains on the stigma. However, since *Ceratina* was most often observed excavating the flowers and appeared to be feeding on the pollen grains, then it appeared to be more of a cowpea flower eater than a pollinator. Also, since the spotted beetles observed in abundance on the cowpea flowers during the major rainy season were mostly found feeding on the cowpea flowers, then the beetles can be described as cowpea flower eaters. Therefore, they can be considered as flower pests.

There is the likelihood that certain condition(s) favour the availability and activities of *Xylocopa* sp and *Megachile* sp. in different seasons of the year because *Xylocopa* sp were very active during the major rainy season but not in the minor rainy season and *Megachile* sp. very active in the minor rainy season but not in the major rainy season

During the major rainy season the percentage fruit set for flowers that were not visited by any organism (unexposed) and the flowers visited by the two most promising insects, namely *X. calens* and thrips were almost the same. However, the highest fruit set was recorded for the unexposed flowers (control). The findings further showed that though unexposed (self-pollinated) flowers recorded the highest fruit set, suggesting that it is possible that cowpea flowers that are not visited by any organism can undertake self-pollination.

A slightly higher number of pods developed from flowers visited by *X. calens* than the unexposed flowers and flowers visited by thrips during the major rainy season. Therefore, there were significant differences between the number of pods formed from flowers visited by various insects and the control flowers. The results here are a further confirmation of the idea from other researchers of cowpea undertaking both self- and cross-pollination.

Though, the cowpea flower thrips *Megalurothrips sjostedti* (Trybom) is considered as one of the most destructive pests attacking the reproductive structures of cowpea during plant development (Tamo *et al*, 1993), it also appears from this study in the major rainy season that in some cases fruit set and pod formation can still take place suggesting that even when the thrips affect the flowers fruit formation and pod development may take place.

There was a lower level of fruit abortion for flowers visited by *X. calens* compared to that of the flowers visited by other insects and the unexposed flowers. However, higher number of pods developed from the fruits formed by flowers visited by *X. calens*. Therefore, it can be said that *X. calens* might have caused cross-pollination which caused the improvement in gamete compatibility leading to formation of more fruits and pods.

In the minor rainy season also, it appeared that *Megachile* sp promised to be an agent of cross- pollination of cowpea flowers because the flowers visited by

Megachile sp.formed more fruits than the unexposed flowers. Consequently, the percentage fruit failure for flowers visited by *Megachile* sp was higher than that for the unexposed flowers. Also, the total number of pods developed from flowers visited by *Megachile* sp was more than those developed from unexposed flowers. This may mean that visitation by insects such as *Megachile* sp to cowpea flowers can be beneficial in increasing the number of fruit set and pods developed.

Both *X. calens* and *Megachile* sp. carried a lot of pollen grains on their bodies. Both insects were also found to move very fast from one flower to another. On the flower, they inserted their tongues down the ovary and their bodies brushed against the tip of the stigma of the flowers. Within one minute, one *X. calens* or *Megachile* sp. visited between 6 to 8 flowers. These characteristics therefore put *Xylocopa calens* and *Megachile* sp. in favorable positions to cause cross-pollination in cowpea.

There was no clear cut relationship between fruit formation and any of the weather conditions (rainfall, temperature and relative humidity) during the major rainy season. Similarly, though there was no clear cut relationship between fruit formation and change in relative humidity during the minor rainy season, increase in rainfall led to increased fruit formation and increase in temperature led to decrease in fruit formation for unexposed (control) flowers.

The findings also suggest that large bees such as *X calens* and *Megachile* sp. are the promising cowpea pollinators because they are able to open the flowers to get their body surfaces that can carry pollen grains touching the tip of the stigma. More seeds per pod were produced when *X. calens* as well as *Megachile* sp.visited the cowpea flowers pointing to cross-pollination of the cowpea flowers caused by the two types of insects.

However, there was no clear cut difference between the seed length as well as seed circumference for flowers visited by *Megachile* sp. and those not visited by any organism. This is an indication that in this study cross-pollination of cowpea by *Megachile* sp. did not lead to formation of bigger seeds than those self-pollinated.

Morphological studies of the progenies of flowers visited by *Megachile* sp. and unexposed flowers

It can be said that progenies of cowpea flowers visited by *Megachile* sp. started flowering earlier than the progenies of unexposed (control) flowers. The difference may be due to characteristics embedded in the seeds obtained from flowers visited by *Megachile* sp. The characteristic might be due to cross-pollination by *Megachile* sp. Therefore the characteristic may be responsible for early flowering and fruiting in progenies of flowers visited by *Megachile* sp.

The drastic reduction in leaf area for progenies of flowers visited by *Megachile* sp. is likely due to cross-pollination of flowers that formed the seeds from the experimental farm in the minor rainy season. Therefore, it will not be out of place to say that cross-pollination of cowpea by *Megachile* sp. can lead to reduction in leaf area of the progenies.

Since the leaves of the progenies of the unexposed flowers were more photosynthetically efficient than leaves of the progenies of flowers visited by *Megachile* sp then it presupposes that whenever *Megachile* sp causes cross-pollination of cowpea the leaves of the progenies may not be photosynthetically efficient. However, since the leaves of progenies of flowers visited by *Megachile* sp.were greener than leaves of the progenies of seeds obtained from unexposed flowers then the result obtained appear to be the direct opposite of what is expected.

The indication from the findings is that whenever *Megachile* sp. visits a cowpea flower, probably causing cross-pollination the progenies will develop more flowers and pods than the progenies of unexposed flowers. Similarly, the pods developed by the progenies of flowers visited by *Megachile* sp. produced more seeds than the pods developed from progenies of unexposed flowers.

Progenies of flowers visited by *Megachile* sp. developed seeds which were longer and having bigger circumference than seeds developed by progenies obtained from flowers not visited by any organism. This suggests that in case *Megachile* sp. causes cross-pollination of cowpea, the seeds formed from the progenies may be bigger than the seeds formed from the progenies of the unexposed flowers. Therefore, it can be said that if cowpea is cross-pollinated by *Megachile* sp. it will lead to higher yield in the offspring of the seeds formed.

Seeds developed from progenies of flowers visited by *Megachile* sp. had lower starch and fibre contents but higher calcium, phosphorus and protein contents than seeds developed from progenies of flowers not visited by any organism (unexposed). Therefore it is possible that eating seeds developed from the progenies of flowers not visited by any organism (control or self-pollinated) will make one to have substantial amount of energy, have better stimulation of the movement of food through the gut, reduced blood cholesterol levels and reduced risk of bowel cancer and gall stones more than eating seeds developed from progenies of flowers visited by *Megachile* sp. Similarly, eating of seeds developed from the progenies of flowers visited by *Megachile* sp. may cause a person to develop healthy teeth and bones, develop the proper functioning of the heart and nervous system, normal contraction of the muscles and clotting of blood more than eating seeds developed from progenies of flowers not visited by any organism. So, in terms of calcium, phosphorus and proteins, seeds developed from progenies of *Megachile* sp. are nutritionally better than seeds from control flowers. However, seeds from progenies of control flowers are nutritionally better in terms of starch and fibre content.

It can also be said that the seeds of the progenies obtained from flowers visited by *Megachile* sp. can be very useful and better sources of protein than seeds of the progenies obtained from flowers not visited by any organism.

The roots of the progenies of flowers visited by *Megachile* sp developed higher number of nodules than the roots of the progenies of the unexposed flowers. Therefore, it is possible that the plants formed from the seeds obtained from flowers visited by *Megachile* sp. may be able to fix much more nitrogen in the soil thereby improving soil fertility for the cultivation of other crops than plants formed from the unexposed flowers.

Recommendations

Farmer and Agricultural Extension Officers' knowledge about cowpea flower visitors within the cowpea agro-ecosystems

In order to attract more females into the Agricultural Extension Service profession the Ministry of Food and Agriculture and other stakeholders should put in place a programme to motivate females to train as Agricultural Extension Officers. It is hoped that involvement of more females in Agricultural Extension Services responsible for cowpea development programmes will equally attract more females into cowpea farming thereby engendering gender balance in cowpea farming and more production of cowpea.

Since the Extension Officers generally have very low academic backgrounds (General Certificate in Agriculture) then there is the need for government to put in place further education programmes that can take care of the academic deficiencies of the Extension Officers. Such programmes can be in the form of sandwich or distance education programmes where the Extension Officers can academically upgrade themselves while still on the job.

Since majority of the farmers have very few years of experience in cowpea farming, there is the need for the agricultural authorities in the districts concerned to make sure that the farmers get the necessary advice that will help them to undertake healthy cowpea farming practices that will allow for maximum production. Also, since majority of the Extension Officers have between 6 and 30 years experience in providing Extension Services, a provision of on the job academic and in-service education programmes should be made available to them by the faculties of agriculture in the universities of the country to help sharpen their professional and academic skills.

From the findings it can be said that cowpea is mainly cultivated at a subsistent level in the research areas. Therefore, in order to raise the production level of the crop to a substantial level in the research areas there is the need for the stakeholders to brainstorm to find out the constraints to the production of the crop on large scale. The solution to such constraints to be identified may help to solve the problem to some extent.

Considering the low numbers of extension staff, it will be in the interest of the Ministry of Food and Agriculture (MOFA) to take immediate steps to train more extension staff to augment the existing numbers in the various districts.

In this study, the farmers and Extension Officers were not asked the source of their information that pollinators can transfer pollen grains from the anther to the stigma. Hence, it is recommended that further research is carried out to investigate the source of that information.

Since almost all the farmers and some Extension Officers have low personal knowledge of pollinators then, it will be very important for government to include introductory courses in pollination and pollinators involving pollinator identification, biology and conservation using an ecosystem approach in Primary, Junior High, Senior High Schools, Agricultural Colleges and University curricula.

The fact that over ninety percent of farmers and all the Agricultural Extension Officers agreed that farmers should be given training in the knowledge of pollinators and their usefulness shows the importance the two parties attached to the subject of pollination. Therefore, it is important for the Ministry of Food and Agriculture (MOFA) to see to such training for the farmers. However, considering the kind of response received from extension officers pertaining to the knowledge covering insect pollinators, it will be advisable for the Ministry of Food and Agriculture to do a number of weeks' intensive courses for the Extension Officers separately on the issue of insect pollinators. The expected outcome of the training should be targeted at improving the economic and social benefits through increasing yield and improving produce quality and management practices.

Since both farmers and Extension Officers clearly showed that they did not know exactly how many times the cowpea plants need to be sprayed before harvest, it is hereby recommended that the Ministry of Food and Agriculture should contract experts to train both farmers and Extension Officers in the best practices of cowpea pest control.

Since neem seed water extract (NSWE) is a promising natural alternative insecticide effective in cowpea pest control but more friendly to beneficial insects than synthetic insecticides the recommendation therefore is that the Ministry of Food and Agriculture together with the universities and research institutions in Ghana should undertake a vigorous research into the use of NSWE for better understanding of its effects on insect pests and pollinators. This will help in using NSWE as a substitute for synthetic pesticides in the control of cowpea field pests in integrated pest management programmes.

Survey and field experiments

Though, *Ceratina* was most often observed excavating the flowers and appeared to be feeding on the pollen grains suggesting that it is cowpea flower eater than pollinator, a further research into the actual role of *Certatina* on cowpea flowers is recommended.

Once condition(s) that favour the availability and activities of *Xylocopa* sp and *Megachile* sp. in different seasons of the year are not yet known it is recommended that further research is carried out to study the possible cause(s) of the occurrence and activities of the two species in the two different seasons of the year.

Though thrips are considered as cowpea flower pests, in this study, findings suggest that in some cases fruit set and pod formation can still take place when thrips affect the flowers. Hence, there is the need for further research to ascertain the actual role of thrips on cowpea flowers.

Though characteristics of *Xylocopa calens* and *Megachile* sp. put them in favorable positions to cause cross-pollination in cowpea, there is the need to undertake another study in the form of genetic analysis to ascertain the deposition of pollen grains from other cowpea plants on stigmas by these insects. It is also suggested that more work should be done to monitor the relationship between weather conditions (rainfall, temperature and relative humidity) and fruit formation in cowpea over a longer period of time where fruit set will depend on changes in the weather conditions. The results of that study will help to explain how changes in weather conditions affect cowpea fruit formation.

A further research is also recommended to find out whether *Megachile* cross-pollination can lead to production of bigger seeds or not.

Morphological studies of the progenies of flowers visited by *Megachile* sp. and unexposed flowers

The drastic reduction in leaf area for progenies of flowers visited by *Megachile* sp. suggesting effects of cross-pollination of flowers that formed the seeds from the experimental farm in the minor rainy season needs further research. Also, there is the need for further studies into finding out how cross-pollination due to *Megachile* sp. can influence photosynthesis in the leaves of the progenies that will be formed. There is also the need to do chlorophyll analysis of the leaves to find out if the leaves of the progenies of flowers visited by *Megachile* sp. have more chlorophyll than leaves of the progenies of the control. It is further recommended that the effects of insects visiting cowpea flowers on nutrient content of the seeds should be further researched to confirm or disprove the findings of this study.

Since the insects observed to have been causing cross-pollination, namely, *Xylocopa calens* and *Megachile* sp are mainly very active between 6 and 10 am, then farmers need to avoid spraying chemicals that can kill them within this period of the day. This way, the two beneficial insects will be conserved to cause cowpea cross-pollination which will in turn cause higher yields and improvement in the nutrient content of the seeds obtained from the progenies.

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APPENDICES

Appendix 1: Questionnaire for cowpea farmers and agricultural extension officers

This questionnaire aims at finding out what cowpea farmers and extension officers know about cowpea insect flower visitors and pest control in cowpea farms. This is a research instrument therefore answers given do not form assessment of the respondents in any form. Hence, names are not needed and the answers will be treated with the confidentiality deserved. Respondents are to tick the correct answer for questions with options in the box provided. Answers should be written in the spaces provided for questions with no options Please be as objective as possible.

A) Personal information

1. Sex: a) Male ☐ b) Female ☐

2. Age::

a) 15 -25 ☐

b) 26 – 35 ☐

c) 36 – 45 ☐

d) 46 – 55 ☐

e) 56+ . ☐

3. What is your highest level of education? (For cowpea farmers only)

a) No formal education ☐

b) Primary school ☐

c) Middle school/JSS ☐

d) Secondary school ☐

e) Agricultural institute ☐

f) Vocational/technical school ☐

g) University ☐

h) Others ☐ State: ....

4. What is your highest academic / professional qualification? **(For extension officers only)**

a) General Certificate in Agriculture ☐

b) Diploma in Agricultural Extension ☐

c) B.Sc. in Extension in Farm Management ☐

d) Others ☐ State:...

5. For how long have you been doing cowpea farming?**(For cowpea farmers only)**

a) 1 – 5 years ☐

b) 6 – 10 years ☐

c) 11 – 15 years ☐

d) 16 – 20 years ☐

e) 21+ years ☐

6. For how long have you been an extension officer? **(For extension officers only)**

a) 1 – 5 years ☐

b) 6 – 10 years ☐

c) 11 – 15 years ☐

d) 16 – 20 years ☐

e) 26 – 30 years ☐

31+ years ☐

7. How many acres of cowpea do you cultivated in a year? **(For cowpea farmers only)**

a) Less than 1 acre ☐

b) 1 - 5 acres ☐

c) 6 – 10 acres ☐

d) 11 – 15 acres ☐

e) 16-20 acres ☐

f) Greater than 20 acres ☐

8. How many cowpea farmers do you have under your care? **(For extension officers only)**

a) 1 – 20

b) 21 – 40

c) 41 – 60

d) 61 – 80

e) 81+

B) Knowledge of pollinators/flower visitors

9. For each of the following insects tick agree if it visits the cowpea flowers and disagree if it does not visit the cowpea flowers (Disagree = 1 and Agree = 2)

	Response	
This insect visits cowpea flowers	**Agree**	**Disagree**
Bees		
butterflies/moths		
ants		
wasps		
beetles		
thrips		

10. For each of the following insects tick the column corresponding to the particular role that it plays on the cowpea flowers

	Role on the cowpea flowers		
Insect	**Predator**	**Pollinator**	**Pest**
Bees			
Butterflies/moths			
Ants			
Wasps			
Beetles			
Thrips			

11. Have you ever heard of pollinators **(If yes go to question12 and if no go to question 17)**

a) Yes ☐ b) No ☐

12. What role do pollinators play on cowpea flowers?

a) They transfer pollen grains from the anther to the stigma [ ]

b) They destroy flowers [ ]

c) They feed on flowers [ ]

d) They guard flowers against pests [ ]

e) Others (state) [ ] ....

13. Do insects also cause pollination?

a) Yes [ ] b) No [ ]

14. How do you rate your knowledge about pollinators?

a) Less than 40% [ ]

b) 40 – 50% [ ]

c) 51- 60% [ ]

d) 61 – 70% [ ]

e) 71 – 80% [ ]

f) 81 – 90% [ ]

g) 91 – 100% [ ]

15. For each of the following statements tick agree or disagree depending on how you consider it

(Disagree = 1 and Agree = 2)

This is a benefit of pollination	Response	
	Disagree	Agree
Increased fruit set /Increased crop yield		
Increased seed viability of seeds		
Faster growth of plants		
Reduction in fruit drop		
Enhanced resistance to diseases		
Increased oil content in oil seed crops		
Increase in the number and size of seeds		
Formation of more nutritive and aromatic fruits		

12. What role do pollinators play on cowpea flowers?

a) They transfer pollen grains from the anther to the stigma ☐

b) They destroy flowers ☐

c) They feed on flowers ☐

d) They guard flowers against pests ☐

e) Others (state) ☐ ....

13. Do insects also cause pollination?

a) Yes ☐ b) No ☐

14. How do you rate your knowledge about pollinators?

a) Less than 40% ☐

b) 40 – 50% ☐

c) 51- 60% ☐

d) 61 – 70% ☐

e) 71 – 80% ☐

f) 81 – 90% ☐

g) 91 – 100% ☐

15. For each of the following statements tick agree or disagree depending on how you consider it

(Disagree = 1 and Agree = 2)

	Response	
This is a benefit of pollination	**Disagree**	**Agree**
Increased fruit set /Increased crop yield		
Increased seed viability of seeds		
Faster growth of plants		
Reduction in fruit drop		
Enhanced resistance to diseases		
Increased oil content in oil seed crops		
Increase in the number and size of seeds		
Formation of more nutritive and aromatic fruits		

16. For each of the following statements tick agree or disagree as you consider it (Disagree = 1 and Agree = 2)

This is a farming practice that destroys flower visitors / pollinators	Response	
	Agree	Disagree
Pesticide application		
Weeding the undergrowth of the crops		
Mixed cropping		
Monocropping		
Harvesting		

17. In your views do you think farmers need some training in the knowledge of pollinators and their usefulness? (For an extension officer who says yes should move on to question 18, if no go to question 21)

a) Yes ☐ b) No ☐

18. If yes to question 17 then why (**For extension officers only**)

....

....

....

19. If yes to question 17 then do you do it for the farmers? (**For extension officers only**)

Yes ☐ No ☐

20. If yes to question 19 then on which topics? (**For extension officers only**)

....

....

....

21. If no to question 17 then why (**For extension officers only**)

....

....

....

....

C) Pest control

22. What is done when pests infest the cowpea plants? (If you selected answer 'a' then continue to answer the rest of the questions)

a) Spray with chemicals [ ]   b) do nothing about it [ ]

23. How often can chemical spraying be done before the crops are harvested?

a) Once [ ]

b) Twice [ ]

c) three times [ ]

d) Four times [ ]

e) Five times [ ]

24. What are the effects of pesticides on insect pollinators?

a) They are killed [ ]

b) It makes them to breed more [ ]

c) No effects [ ]

d) Do not know [ ]

e) Others (state) [ ] ....

25. After the chemical application are only the pests killed or other insects are also killed? (If you selected answer 'a 'go to question 27 and if you selected answer 'b'go to question 26)

a) Only the pests are killed [ ]   b) other insects are also killed [ ]

26. If other insect apart from pests are killed after spraying chemicals then agree or disagree with each of the following by ticking the appropriate column (Disagree = 1 and agree = 2)

This is one of the other insects on cowpea flowers killed after spraying chemicals	Response	
	Agree	Disagree
Bees		
butterflies/moths		
wasps		
beetles		
ants		

27. Agree or disagree with each of the following (Disagree = 1 and agree = 2)

This is age of cowpea plants at which chemical spraying is done	**Response**	
	Agree	**Disagree**
Before flowering		
during flowering		
at fruiting stage		
Throughout the cropping period		
any time pests emerge		

28. Agree or disagree with each of the following

This is a pest control measure available to farmers other than chemical application	**Response**	
	Agree	**Disagree**
Biological control (pathogens, predators, parasitoids)		
Use of pest resistance varieties		
Control by cultural practices (crop spacing, type of cropping, time of sowing)		
None of the above		

29. Do cowpea farmers receive advice from agricultural extension officers on chemical application? (If yes then continue to question 30, if no then go to question 31)

a) Yes ☐ b) No ☐

30. If yes to question 29 then agree or disagree with each of the following by ticking the appropriate column (Disagree = 1 and agree = 2)

Yes, farmers are advised on chemical application on topic such as	**Response**	
	Agree	**Disagree**
Types of chemical to apply for a particular pest		
The concentration of the chemical to be applied		
Number of times to spray the chemical before harvesting the crop		
Time of the day for application		
Growth stage of the plants when chemical application can be done		
Pest population demanding chemical application		

31. In case you spray chemicals then give the name(s) of the pesticides (s) that you normally spray:

a)……………………………………………………………………………………………

b)……………………………………………………………………………………………

c)……………………………………………………………………………………………

Appendix 2: Farmer Field Survey Detail Results

Insects observed on cowpea flowers during survey of cowpea farms from 16/12/05 to 10/01/06 have been presented on table 9.Throughout the survey, the insects observed on the flowers were bees such as *Apis mellifera* (Hymenoptera: Apidae - Apinae) (Plate 12), *Ceratina* sp. (Plate 13), *Megachile* sp (Hymenoptera: Megachilidae - Megachilinae) Plate 14). *Lasioglossium* sp (Plate 15), Xylocopa *calens* (Hymenoptera: Anthophoridae – Xylocopinae) (Plate16), and non-bees such as thrips, flies, (Plate 17) butterflies / moths, wasps (Plate 18) and ants. Plot one was surrounded by *Chromolaina odorata* (Acheampong weeds). From plot one it is clear that the commonest insects are thrips mostly observed on the petals, followed by flies mostly observed on the tip of the keel. The differences between the total number of insects were very highly significant (X^2 = 127.52; P = 0.001). The trend is almost the same for all the plots. In almost all cases thrips were the most common insects followed by flies. Plot two was surrounded by *Chromolaena odorata* (Acheampong weeds) and elephant grass. The differences between the total numbers of insects were very highly significant (X^2 = 31.82; P = 0.001). Plot three was surrounded by *Chromolaina odorata* (Acheampong weeds) and maize. The differences between the total numbers of insects were very highly significant (X^2 = 52.53; P = 0.001). Plot four was also surrounded by *Chromolaina odorata* (Acheampong weeds). The differences between the total numbers of insects were highly significant (X^2 = 144.75; P = 0.001).

Plot five was also surrounded by *Chromolaina odorata* (Acheampong weeds). Plot six was surrounded by forest and *Chromolaina odorata* (Acheampong weeds). Plots seven, eight and nine were all surrounded by *Chromolaina odorata* (Acheampong weeds). Plot 10 was surrounded by forest, plot 11 by elephant grass and *Chromolaina odorata* (Acheampong weeds), plot 12 by *Chromolaina odorata* (Acheampong weeds) and plot 13 by elephant grass and *Chromolaina odorata* (Acheampong weeds).

Appendix 2: Insects observed on cowpea flowers when farms were surveyed

Plot / Type of insect	Position on Flower						TOTAL	
	On petals		On tip of stigma		Inside flower			
	Freq	% freq	Freq	% freq	Freq	% freq	Freq	% freq
Plot 1:							N = 106	
Apis mellifera	2	1.89	6	5.66	0	0	8	7.55
Ceratina sp.	3	2.83	7	6.60	0	0	10	9.43
Thrips	22	20.75	18	16.98	19	47.37	59	55.66
Crickets	2	1.89	0	0	0	0	2	1.89
Flies	8	7.55	13	12.26	0	0	21	19.81
Butterflies / moths	4	3.77	2	1.89	0	0	6	5:66
						$X^2 = 127.52$		
Plot 2:							N = 70	
Apis mellifera	1	1.43	4	5.71	0	0	5	7.14
Ceratina sp.	3	4.29	8	11.43	2	2.86	13	18.57
Megachile sp	2	2.86	4	5.71	0	0	6	8.57
Thrips	6	8.57	12	17.14	7	10.00	25	35.71
Flies	7	10.00	11	15.71	0	0	18	25.71
Butterflies / moths	3	4.29	0	0	0	0	3	4.29
							$X^2 = 31.82$	
Plot 3							N = 83	
Apis mellifera	0	0	5	6.02	0	0	5	6.02
Ceratina sp.	0	0	7	8.43	2	2.41	9	10.84
Lasioglosum sp	0	0	4	4.82	0	0	4	4.82
Thrips	13	15.66	14	16.87	7	8.43	34	41.0

Flies	6	7.23	5	6.02	0	0	11	13.25
Butterflies / moths	5	6.02	7	8.43	0	0	12	14.46
Ants	0	0	0	0	8	9.64	8	9.64
					$X^2 = 52.53$			
Plot 4							N = 112	
Apis mellifera	0	0	3	2.68	0	0	3	2.68
Lasioglosum sp	0	0	13	11.61	0	0	13	11.61
Thrips	20	17.86	28	25.00	3	2.68	51	45.54
Flies	18	16.07	18	16.07	0	0	36	32.14
Butterflies / moths	0	0	2	1.79	0	0	2	1.78
Beetles	2	1.79	3	2.68	0	0	5	4.46
Wasp	2	1.79	0	0	0	0	2	1.78
					$X^2 = 144.75$			
Plot 5							N = 38	
Apis mellifera	0	0	5	13.16	0	0	5	13.16
Lasioglosum sp	2	5.26	6	15.79	0	0	8	21.05
Thrips	7	18.42	3	7.89	5	13.16	15	39.47
Flies	2	5.26	3	7.89	0	0	5	13.16
Butterflies / moths	5	13.16	0	0	0	0	5	13.16
Plot 6							N = 127	
Lasioglosum sp.	0	0	10	7.87	0	0	10	7.87
Megachile sp	0	0	7	5.51	0	0	7	5.51
Thrips	15	11.81	20	15.75	15	11.81	50	39.37
Flies	15	11.81	22	17.32	0	0	37	29.13
Butterflies / moths	15	11.81	8	6.30	0	0	23	18.11

Plot 7							**N = 41**	
Lasioglosum sp.	4	9.76	8	19.51	0	0	12	29.27
Thrips	15	36.56	13	31.71	0	0	28	68.29
Butterflies / moths	1	2.44	0	0	0	0	1	2.44
Plot 8							**N = 155**	
Lasioglosum sp.	0	0	5	3.23	0	0	5	3.23
Thrips	20	36.36	30	19.35	30	19.35	80	51.61
Flies	30	19.35	33	21.29	0	0	63	40.65
Butterflies / moths	5	3.23	2	1.39	0	0	7	4.52
Plot 9							**N = 110**	
Lasioglosum sp.	5	4.55	10	9.09	0	0	15	13.64
Thrips	25	22.73	19	17.27	14	12.73	58	52.73
Flies	10	9.09	11	10.0	0	0	21	19.09
Butterflies / moths	7	6.36	9	8.18	0	0	16	14.55
Plot 10							**N = 60**	
Apis mellifera	3	5.00	6	10.00	0	0	9	15.0
Lasioglosum sp.	4	6.67	8	13.33	0	0	12	20.0
Thrips	10	16.67	7	11.67	0	0	17	28.33
Flies	14	23.33	8	13.33	0	0	22	35.0
Plot 11							**N = 113**	
Apis mellifera	5	4.42	16	14.16	0	0	21	18.58
Xylocopa calens	2	1.77	3	2.65	0	0	5	4.42
Thrips	17	15.04	14	12.39	11	9.73	42	37.17
Butterflies / moths	9	7.96	6	5.31	0	0	15	13.27

Ants	10	8.85	7	6.19	13	11.50	30	26.55
								X^2 =
Plot 12							**N = 29**	
Lasioglosum sp.	7	24.14	16	55.17	0	0	23	79.31
Flies	1	3.45	3	10.34	0	0	4	13.79
Butterflies / moth	2	6.90	0	0	0	0	2	6.90
Plot 13					**N = 68**			
Megachile sp.	5	7.35	18	26.47	0	0	23	33.82
Ceratina sp.	0	0	2	2.94	0	0	2	2.94
Thrips	8	11.76	13	19.12	10	14.71	31	45.59
Flies	2	2.94	3	4.41	0	0	5	7.35
Butterflies / moth	4	5.88	3	4.41	0	0	7	10.29