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UNIVERSITY OF GHANA

COLLEGE OF BASIC AND APPLIED SCIENCES

**SUSCEPTIBILITY OF FIVE COWPEA VARIETIES TO FIELD AND STORAGE  
INSECT PESTS**

**BY**

**BAFFOE- ANSAH JOSHUA**

**10806167**

**THIS THESIS IS SUBMITTED TO THE UNIVERSITY OF GHANA, LEGON IN  
PARTIAL FULFILLMENT OF THE REQUIREMENT FOR THE AWARD OF  
MPHIL ENTOMOLOGY DEGREE.**



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**\*Joint Interfaculty International Programme for the Training of Entomologists in West  
Africa. Collaborating Departments: Animal Biology and Conservation Sciences (School of  
Biological Sciences) and Crop Science (School of Agriculture) University of Ghana, Legon**

DECLARATION

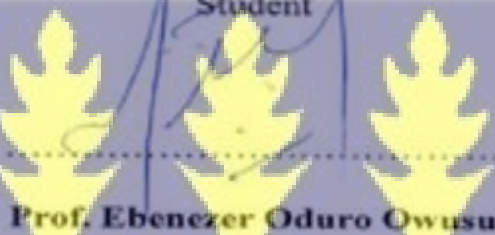
This is to certify that this thesis, with exception of references to other scholars' work which has been acknowledged duly, is the result of research work undertaken by BAFFOE - ANSAH JOSHUA at the University of Ghana towards the award of the Master of Philosophy in Entomology at Africa Regional Postgraduate Program in Insect Science, University of Ghana.



**Joshua Baffoe-Ansah**

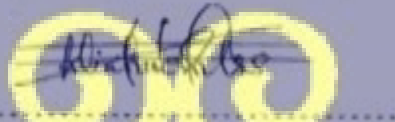
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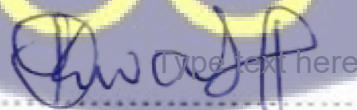
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### DEDICATION

This work is dedicated to God Almighty for His provision and sustenance. I also dedicate it to my beloved children, Ewurabena Sompa Baffoe-Ansah and Nana Kwaku Nkonim Baffoe-Ansah. Finally, I dedicate the work as well to the entire Ofosu Mensah family.



## ACKNOWLEDGEMENT

I am most grateful to the Almighty God the abundant grace, strength, provision and during the period of study.

I express my heartfelt gratitude to my supervisors, Prof. Ebenezer Oduro Owusu and Dr. Silas W. Avicor for their patience, guidance, direction, and criticism.

I am thankful to Prof. Isaac K. Asante for his selfless assistance with the acquisition of cowpea seeds, advice and guidance towards my field and laboratory study.

My profound thanks to the former coordinator, Dr. Maxwell K. Billah, who was instrumental and open to all his students, and their study and research concerns. To all ARPPIS lecturers whose immerse support and words of encouragement has brought me this far, especially, Prof. Rosina I. Kyerematen and Dr. Thomas Buxton. God bless them.

My sincere thanks to Ghana Education Trust Fund (GETFund), for sponsoring my tuition.

Lots of appreciation to teaching assistants at the departments of Chemistry, Plant and Environmental Biology, and Crop Science; Barbara Anibea, Henry Mensah and Frank Opoku Agyeman, respectively, who assisted me at all times with my qualitative and quantitative phytochemical analysis, and my data and statistical analysis respectively.

I am grateful to all workers in the University of Ghana experimental farm, especially, Mr. Nicholas Adjekum, Mr. Stephen Atsu and Mr. Ayao, for the assistance towards my field preparation and design.

I appreciate the field and laboratory work assistance given me by my colleagues (ARPIS 2019/21 students), especially, Prosper Asamoah Mensah, Miriam Semefa Mantey and Samuel Adjei Mensah.

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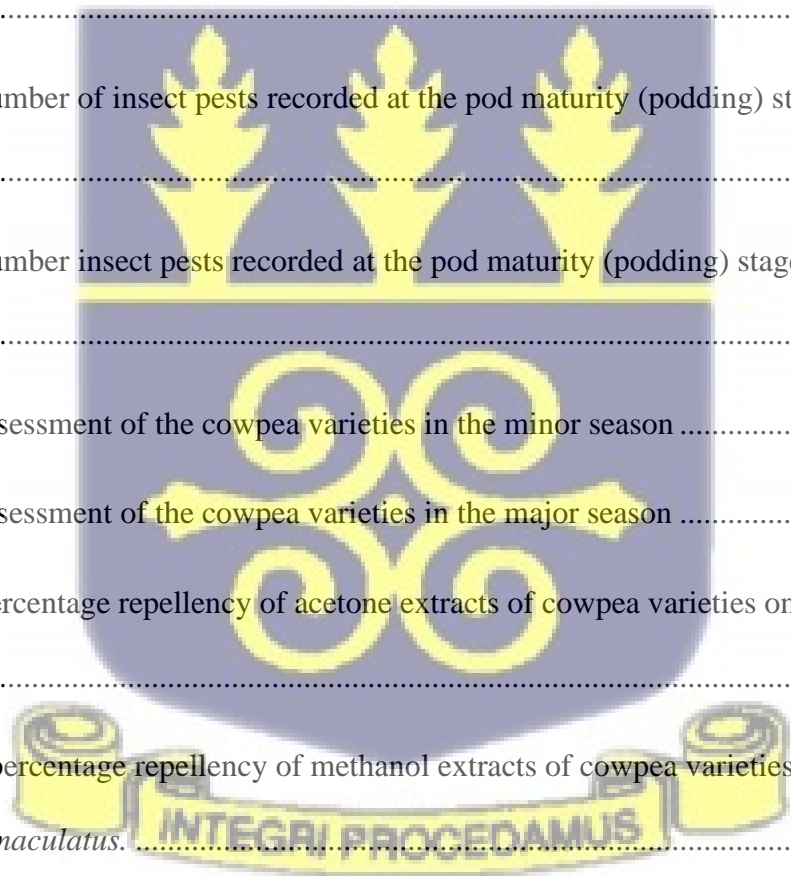
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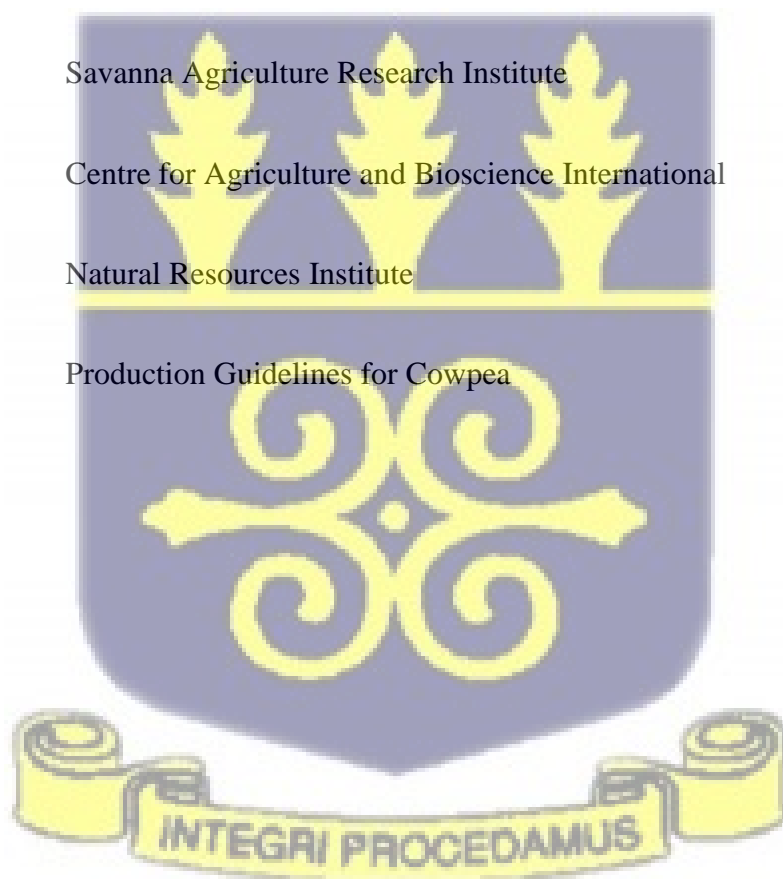
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### LIST OF ABBREVIATIONS

ANOVA	Analysis of Variance
CRD	Complete Randomized Design
FAOSTAT	Food and Agriculture Organization Statistic
IITA	International Institute of Tropical Agriculture
LSD	Least Significant Difference
MDP	Median Development Period
MoFA	Ministry of Food and Agriculture
DABCS	Department of Animal Biology and Conservation Science
CSIR	Council for Scientific and Industrial Research
SARI	Savanna Agriculture Research Institute
CABI	Centre for Agriculture and Bioscience International
NRI	Natural Resources Institute
PGC	Production Guidelines for Cowpea



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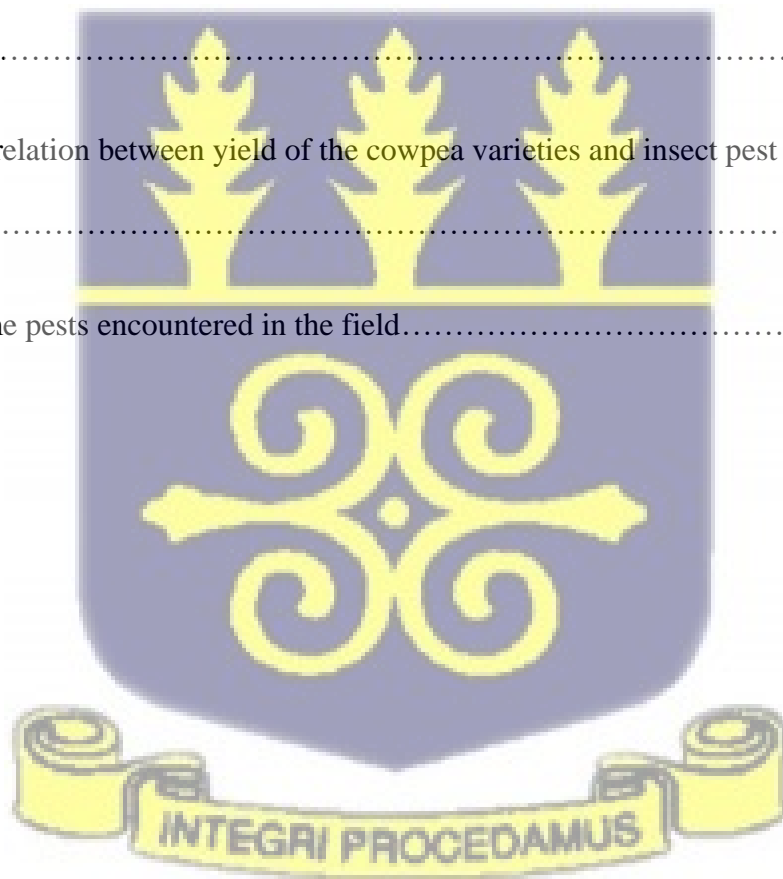
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## ABSTRACT

Cowpea, *Vigna unguiculata*, is a popular food crop in the tropics and subtropics. The crop is particularly susceptible to pests and diseases, limiting its yield. Cowpea cultivars that are resistant to pests in the field and in storage are becoming increasingly significant. Five improved cowpea varieties were screened ('Asontem', 'Golinga', Kirk house, 'Padi Tuya' and 'Wang Kae') for their susceptibility to field and storage insect pests. The field experiment was laid out in a Randomized Complete Block Design with five treatments and four replicates. The insect pests encountered were identified and recorded. Mean yield parameters such as number of pods per plant, weight of pods per plant, length of pod, number of seeds per pod, number of loci per pod, seed weight per pod, 100-seed weight, and total yield were assessed. In the minor season, 'Golinga' recorded the highest number of pods per plant, while 'Padi Tuya' had the least number of pods per plant. Meanwhile, 'Asontem' recorded the highest yield of 71.7 g in the minor season, while 'Padi Tuya' recorded the least value of 60.4 g. In the major season, 'Wang Kae' recorded the highest number of pods per plant, while 'Padi Tuya' recorded the least number of pods per plant. 'Asontem' again recorded the highest total yield of 74.1 g while 'Padi Tuya' recorded the least mean total yield of 59.2 g.

Correlation between insect infestations and yield of the varieties in the field was determined. *Aphis craccivora* infestation was negatively correlated ( $r = -0.2368$ ,  $p > 0.05$ ) with total yield in the major season. *Megalurothrips sjostedti* infestation was negatively correlated with the total yield ( $r = -0.0784$ ,  $P > 0.005$ ) in the major season, and was also negatively correlated with the total yield ( $r = -0.4232$ ,  $P > 0.01$ ) in the minor season. *Maruca vitrata* infestation was positively correlated with the total yield ( $r = 0.0636$ ,  $P > 0.05$ ) in the major season, while it was negatively correlated with total yield ( $r = -0.3767$ ,  $P > 0.01$ ) in the minor season.

The laboratory experiment was laid out in a Completely Randomized Block Design with five treatments and three replicates. There was significant repellence of *Callosobruchus maculatus* by

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the different concentrations (1g/mL and 2g/mL) of the five cowpea extracts. All five cowpea varieties recorded *C. maculatus* mortalities after 4 days of introducing the adult insects onto the seeds. The five cowpea varieties recorded some levels of damage for the six-week period after introduction of *C. maculatus*. *C. maculatus* infestations and seed weight during storage were determined after the six-week period. The median development period of the *C. maculatus* in the five cowpea varieties ranged from 17 to 28 days, with four out of the five varieties ('Asontem', 'Golinga', 'Kirkhouse' and 'Wang Kae') classified as moderately resistant to insect infestation, and one ('Padi Tuya') classified as susceptible to insect infestation. Qualitative and quantitative phytochemical analysis on the cowpea varieties confirmed the presence of different levels of phenols, flavonoids, tannins, and alkaloids.



## CHAPTER ONE

### 1.0 INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) (Walp.), belongs to the Family Fabaceae. It is usually cultivated mainly for its grains and foliage. It is considered as one of the oldest crops used for human consumption and said to have been used as a crop plant since the Neolithic times (Summerfield *et al.*, 1974). It is recognized as one of the African nutrient-rich legumes with the potential of promoting food and nutrient security in the sub-Saharan regions of Africa (Owade *et al.*, 2019).

It is extensively cultivated in Africa in about 16 countries, producing two-thirds of the world's total cowpea (Winrock, 1992). In Africa, Ghana is the fifth highest producer of the legume, with an average annual production of 143,000 MT on about 156,000 hectares (Haruna *et al.*, 2020). Cowpea is the second most important legume in the northern part of Ghana, after groundnuts in terms of area of cultivation, quantity produced, and annual consumption (Egbadzor *et al.*, 2013). However, yields in Ghana are classified amongst the lowest worldwide with an average production rate of 310 kg/ha (Ofosu-Budu *et al.*, 2007).

*Vigna unguiculata* is a very significant crop in Africa since it is an affordable and readily available source of dietary protein in the cuisine of Africans. According to studies by Addai and Ghanney (2018), cowpea contains 20 to 25 % of protein, which is about twice the protein content found in most cereals. Cowpea is primarily valued as food for humans but can also be used as fodder for livestock. The cowpea pod husks acquired after threshing are usually used as feed for livestock (Oluokun, 2005). As a result, it is a very crucial trade component in the economies of rural communities as the farmers are actively involved in the cowpea trade (Kusi *et al.*, 2019).

The Food and Agriculture Organisation (FAO, 2006) stated that the cowpea crop, if given much attention, would have the potential of supporting the livelihoods of 850 million individuals worldwide as a result of its versatility. Thus, decreasing the high incidence of undernourishment in

sub-Saharan Africa. As a result, efforts have been made to improve the production of the legume in Ghana through several methods such as the introduction of new and high yielding varieties of cowpea in the field (Agyeman *et al.*, 2015).

Cowpea thrives under dry conditions, growing well in soils with up to 85 % sand (Obatolu, 2003). As a result of its high resistance to drought, it is usually cultivated in many underdeveloped parts of the world (Davis *et al.*, 1991). According to Aikins and Afuakwa (2008), the crop is capable of fixing about 240 kg/ha of atmospheric nitrogen into the soil and makes available to succeeding crops grown in rotation with about 60 to 70 kg/ha of atmospheric nitrogen.

Insect pests attack is a major factor which contributes to the low yields of cowpea in Africa as they affect the crop at every stage of its growth. In Ghana, the major field pests of cowpea include the aphid, *Aphis craccivora*, the Flower bud thrip, *Megalurothrips sjostedti* and the pod borer, *Maruca vitrata* (Baidoo and Mochiah, 2014). According to Jayasinghe *et al.* (2015), *Maruca vitrata* causes the most damage to the developing cowpea crop as a result of its cosmopolitan distribution. The infestation of *M. vitrata* on cowpea crops results in 20 to 88 % loss of yield (Jayasinghe *et al.*, 2015). *Callosobruchus maculatus* is a common storage pest found on every continent except Antarctica, and causes serious damage in the store (Obeng-Ofori, 2008).

### 1.1 Justification

In Ghana, the cowpea crop is extensively cultivated in the savannah and transitional agro ecological zones. However, the bulk of the grain production is usually done in the northern part of the country (CSIR-SARI, 2012). Despite Ghana being one of the highest cowpea-producing countries in Africa, it is considered as one of the lowest worldwide (Ofosu-Budu *et al.*, 2007). The different varieties of the cowpea crop are also highly susceptible to damage by insect pests both in the field and in storage. The damage caused by these pests limits the production of the legume, leading to low yields and economic losses to the farmer.

Several insecticides have been developed to manage insect pests of cowpea. Insecticide use, on the other hand, can be linked to health issues such as the deposit of active ingredient residues in crops (Mogbo *et al.*, 2014). The use of insect-resistant varieties is an easy and inexpensive alternative to insecticides and a cheaper approach to reduction of the damage caused by pests (Jackai and Asante, 2001).

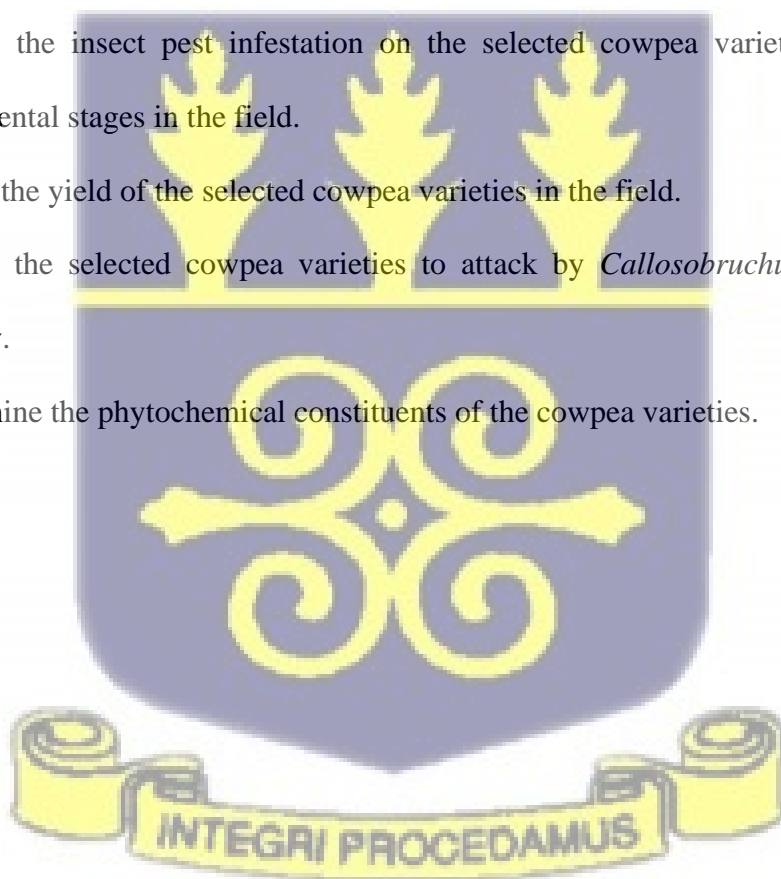
## 1.2 Objectives

### 1.2.1 Main objective

The main objective of the study is to assess selected cowpea varieties for field and storage insect pests.

### 1.2.2 Specific objectives

1. To assess the insect pest infestation on the selected cowpea varieties at the different developmental stages in the field.
2. To assess the yield of the selected cowpea varieties in the field.
3. To assess the selected cowpea varieties to attack by *Callosobruchus maculatus* in the laboratory.
4. To determine the phytochemical constituents of the cowpea varieties.



## 2.0 LITERATURE REVIEW

### 2.1 Origin, Botany and Distribution of Cowpea

Cowpea cultivation lacks archaeological evidence, making its precise origins impossible to trace. As a result, there are several competing theories about whether the crop originated in Africa, Asia, or South America (Seidu, 2019). According to others, cowpea is also said to have originated in Southern Africa. The abundance of the most basic wild cowpea varieties led to the hypothesis that the Republic of South Africa's northern region was the epicenter of cowpea diversity (PGC, 2014)

Cowpea does well on various soil types. It does best in well-drained, fertile, sandy-loam soils (Oyewale and Bamaiyi, 2013). Notwithstanding its centre of origin, cowpea is widely grown in many countries such as Australia, Asia, Brazil, Africa, the Caribbean, India, and the United States of America (Oyewale and Bamaiyi, 2013). The significant zones of production may be found in Central and West Africa including countries like Burkina Faso, Cameroon, Democratic Republic of Congo, Mali, Nigeria, Niger, and Senegal, which in total represent about 89 % of the overall zone of world production (FAO, 2008). Other major production regions include Mozambique, Tanzania, Uganda, Sudan, Kenya, and Somalia. In Africa, cowpea can be cultivated at high altitudes, up to 1800 m but it is mainly grown on the lowlands. Due to cowpea's sensitivity to frost, it is usually grown in warmer regions, producing maximum yield with as little as 300 mm of rainfall (Gomez, 2003). Its long taproot together with mechanisms such as the turning of its leaves upwards and closure of the stomata makes it more tolerant to drought than other leguminous crops such as soybean (Gomez, 2003). Cowpea's high resistance to drought makes it an important crop in many underdeveloped parts of the world (Davis *et al.*, 1991).

The length of the growing season of cowpea varies with type and is also affected by the climate. The determinate type takes 100 days, 110 days in the semi-determinate type, and 120 days in the ranking type. The hotter the weather, the shorter the maturity period of the cowpea (Van Rij, 1999). There is a high level of morphological diversity within the various species including their

growth habits (Porter *et al.*, 1975). The varying growth habits of cowpea range from erect, semi-erect or trailing, and climbing. Cowpea is mainly grown for its seeds, which is high in protein.

*Vigna unguiculata* also exhibits significant variation in its leaves. Generally, the leaves are compound with asymmetrical side leaflets and a cylindrical terminal leaflet (Pottorf *et al.*, 2012). Clusters of flowers may be found at the end of the flower stalk with 2 to 3 seed pods per peduncle. The pods are cylindrical and curved in shape, with a smooth surface and can grow up to 35 cm in length. Pod colour is usually green, yellow, or purple as the seeds reach the green-mature stage for use as a vegetable. As the seeds dry, the pods become tan or yellow in colour. The leaves are usually dark green in colour and show a considerable variation in size and shape, with leaf petiole ranging from 5 to 25 cm long.

Cowpea seeds also vary in size, colour and texture. Seed pods may contain 6 to 13 seeds which are usually kidney shaped. However, the seeds may be more spherical when restricted within the pod during seed development (Sheahan, 2012). Seeds may range in size from the very small wild types to almost 10 cm in cultivated varieties (Rawal, 1975). The seed coats of cowpea may be smooth or rough, may be speckled, blotched or mottled with varying colours such as white, red, brown and black (Davis *et al.*, 1991).

## 2.2 Economic Importance of Cowpea

Cowpea is regarded as one of the most important economic crops globally, especially in the developing regions, as a result of its high protein content, ability to adapt to several soil types, resistance to drought, and ability to improve soil fertility by nitrogen fixation. Other parts of the crop, such as the stems and leaves can also be used as fodder for livestock. The sale of these items serves as a source of income for the farmers.

Cowpea forms a part of the most important groups of crops, providing humans with food, feed for many livestock and income to numerous households, especially in the tropical and subtropical regions (Erana *et al.*, 2020). This is because it is a major source of protein and carbohydrate diet

for several individuals. Cowpea is not only rich in nutrients but also rich in dietary fiber, antioxidants and polysaturated fatty acids and polyphenols (Carneiro da Silva *et al.*, 2018).

The grains of cowpea, both fresh and dry are an important source of food during the period which occurs before the harvest of other cereal crops in many local communities of the West African savannah zones. As a result, the cowpea grain is considered as the most important and most useful part of the cowpea plant for human consumption. The seeds are usually consumed after cooking. In Ghana, it is normally boiled and eaten whole with fried plantain or can be used in a dish locally known as “waakye” (Beans and rice put together). In Nigeria, cowpea paste is either steamed or fried to produce dishes such as “moinmoin” and “akara”, respectively. The rest of the plant may also be dried and used as feed for livestock (Gómez, 2004).

### 2.3 Uses and Nutritional Composition of Cowpea

Recent estimates state that malnutrition is responsible for more than one-third of all child deaths globally. Malnutrition in children was associated with 54 % of deaths in children in developing countries (Bain *et al.*, 2013). According to Michaelsen *et al.* (2009), this is mainly as a result of the consumption of high cereal-based meals, which are bulky, less nutritious, and are energy-giving. Leguminous foods are regarded as main plant sources of energy and good quality proteins (Jayathilake *et al.*, 2018). Cowpea has therefore been endorsed as a high-quality protein constituent of the daily diet composition among financially challenged communities in developing countries, with the main aim of minimizing the high occurrence of protein and energy malnutrition among children (Animasaun *et al.*, 2015). When dry, an average cowpea grain contains 23 – 32 % protein, 50 – 60 % carbohydrate and about 1 % fat (Jayathilake *et al.*, 2018), with its total protein content being approximately 2 - 4 times greater than other cereal and tuber crops (Sebetha *et al.*, 2014).

Cowpea serves as a source of income for many farmers, especially those in the rural communities through the sale of harvested grains. It is considered as the most important crop legume after

groundnut in regards to area of cultivation, quantity produced and yearly consumption in Ghana (Egbadzor *et al.*, 2013). It is also a very important commodity in farming systems, especially in West Africa as a result of its ability to restore soil fertility for preceding cereal crops such as maize and millet through its natural process of atmospheric nitrogen fixation (Saginga *et al.*, 2003)

## 2.4 Production Estimates of Cowpea

Most cowpeas are grown on the African continent, along the southern regions from West Africa to East Africa and southwards. Major producers of cowpea in the Sahel region include Ghana, Mali, and Burkina Faso among others, with Niger being the major cowpea exporter and Nigeria being the main importer of cowpea. Nigeria is responsible for 48 % of cowpea production in Africa and 46 % worldwide and harvesting about 3.7 million hectares annually. According to Singh *et al.* (1997), cowpeas are grown on 12.5 million hectares and have a worldwide production of 3 million tonnes, though estimating the world cowpea production is a difficult task since it is usually grown for subsistence purposes. Estimating the production levels of cowpea is also difficult since it is also grown in mixture with other crops. For instance, in South Sudan, data on the cowpea crop is very scarce and usually inconsistent, if available (FAO/WFP, 2012).

The cowpea crop can be harvested in 3 stages; when the pods are young and green, mature, and green and dry. All stages of the crop may also be used for various purposes. It is mainly cultivated in the western parts of Central and Eastern Equatoria in South Sudan for its leaves to be consumed as vegetables. In Western Equatoria, it is usually grown for its seeds and in the Yei County, it is grown for both seeds and leaves (Ngalamu *et al.*, 2015). The production rate of cowpea in countries such as Brazil, Ghana, Cuba, Nigeria and Zimbabwe, continue to increase as a result of the availability of improved cowpea varieties in these regions (Ngalamu *et al.*, 2015).

## 2.5 Insect pests of cowpea

Cowpea is susceptible at all stages of growth to pests and disease-causing organisms (Ambang *et al.*, 2009). The common pests that attack cowpeas include the aphid, *Aphis craccivora* Koch

(Homoptera: Aphididae), Flower beetle, *Euphoria sepulcralis* (Fabricius) (Coleoptera: Scarabaeidae), Pod borer, *Maruca vitrata* Fabricius (syn. *M. testulalis*) (Lepidoptera: Pyralidae), Bean fly, *Ophiomyia phaseoli* (Trybon) (Diptera: Agromyzidae), Leaf hopper, *Empoasca dolichi* Paoli (Hemiptera: Cicadelidae), and cowpea bruchid, *Callosobruchus* spp. (Coleoptera: Bruchidae) (Nkomah, 2013).

### 2.5.1 *Aphis craccivora*

The Cowpea aphid, *Aphis craccivora* is a general feeder that infests a large number of crops such as carrots, cotton, peanuts and other legumes. It attacks cowpea at the pre flowering stage. Cowpea aphids are shiny black insects that vary in size and biology depending on the climate and soil.

In the tropics it is exclusively anholocyclic, meaning it has a life cycle in which there is a complete lack of male insects. Hence, only females (winged and wingless) are normally encountered, with parthenogenetic reproduction occurring throughout the year. Generally, adult aphids are wingless, but there are some winged forms. Aphids have a high reproductive rate and according to Powell *et al.* (2006), in a space of just about 14 days, wingless female adults can produce about 80 nymphs. This reproductive rate causes large colonies to quickly form mostly under the leaves and young shoots, which are the feeding sites. The transformation of nymphs into adults can take up to 22 days at low temperatures. However, development takes only five days at temperatures around 29 °C (CIPM, 2010), and many generations can be produced in a year. The majority of nymphs mature into wingless females, but winged females emerge from time to time and migrate to new host plants (Powell *et al.*, 2006). When the food source becomes depleted or scarce, the insect's ability to produce winged individuals allows it to migrate to new host plants.

When largely populated, aphids cause direct feeding damage to plants, resulting in stunting, leaf distortion, premature defoliation, and seedling death. *Aphis craccivora* excretes copious amounts of honeydew (a sweet and watery anal excrement) that serves as a medium for the growth of sooty mold which reduces photosynthetic activity (Elmer *et al.*, 1975). Aphids do not only cause direct

damage to their host, but serve as a vector of many plant diseases such as the cowpea aphid-borne mosaic virus which causes substantially greater losses than damage caused by the direct feeding injury (Adu-Dapaah *et al.*, 2005)

### 2.5.2 *Megalurothrips sjostedti*

*Megalurothrips sjostedti*, or legume Flower thrips, is a major insect pest of leguminous plants, particularly cowpea (Bayleyegn *et al.*, 2015). It attacks cowpeas at all stages of development, from pre-flowering through to flowering. In tropical Africa, thrips are abundant and one of the most significant insect pests that attacks cowpea and other leguminous plants, inflicting yield losses of up to 100 %. Adult thrips are little, shiny and slender-winged black insects, which feed on flower buds and flowers (Singh and Allen, 1979). Thrips populations are normally lower following heavy rains but increase during dry conditions associated with the later phases of crop growth (NRI, 1996).

Most members of the family Thripidae (Order Thysanoptera) have been shown to have a six-stage life cycle that includes an egg, two active larval stages, an inactive and non-feeding pupal stage, and an adult stage (male and female) (Reitz, 2009). Under warm conditions, the full life cycle of thrips takes 14-18 days, and this provides them a tremendous capability for increase (Gitonga *et al.*, 2002). The eggs are very tiny, laid in the buds and calyx of developing flowers, and nymphs feed and cause extensive damage (NRI, 1996).

The nymphs and adults of legume Flower thrips are the damaging stages and may damage the terminal leaf buds and petioles during the pre-flowering period. Petioles and leaves that are attacked have little spots surrounded by discoloured areas. Open flowers get distorted and discoloured when the thrips population is very large (Singh and Allen, 1979), this leading to the formation of few pods as the flowers drop prematurely.

Peduncles, for the most part, do not elongate, while plants that are severely infested do not produce any flowers (Singh and Allen, 1979). Thrips feed on pollen, causing pollination and seed

set to decline. Thrips actively migrate between hosts in search of better food sources, while their direct feeding destroys buds and flowers, as well as causing pod abnormalities (Bayleyegn *et al.*, 2015). In addition to causing direct damage, thrips are vectors for tospoviruses, which inflict considerable damage to many plant species.

### 2.5.3 *Maruca vitrata*

*Maruca vitrata*, also known as the legume pod borer, is a widely distributed species in Africa and Southeast Asia. It can be found all over the tropics and subtropics, where it may cause extreme damage (Adati *et al.*, 2007). The adult is a light brown nocturnal moth that can live for about 10 to 12 days (Usua and Singh, 1979). Mating takes place during this time, and the female deposits up to 150 eggs on the leaf buds, flower buds, and flowers. At 24-27 °C, eggs hatch in around three days (Ramasubramanian and SundaraBabu, 1989). There are five larval instars (Odebiyi, 1981) which together last 8-14 days until pupae develop in the soil (Okeyo-Owuor and Ochieng, 1981).

The larvae, which are dull to yellowish, are the stages of economic importance. During the larval development period, the larva can consume four to six flowers by moving from one flower to another (Taylor, 1967). Flower abscission is common as a result of their feeding habits (Jackai *et al.*, 1992). *Maruca* larvae feed on stems, peduncles, flower buds, and pods (Zhu-Salzman and Murdock, 2007). Flowers that have been attacked may be discoloured, and reproductive components may be damaged or absent (Atachi, 1998). Flower buds are shed, and pod production is reduced as a result of damage from *Maruca* larvae. Small, darker entry holes can be found on the surface of damaged pods. The adults, however, do not feed on cowpea like the larvae. They feed on pollen, and as such cause little to no damage to the pods.

### 2.5.4 *Riptortus dentipes*

*Riptortus dentipes* is a significant pod-sucking pest of cowpea in tropical Africa and Asia. Its life cycle is such that it can be seen in great numbers in late May and early June, when early cowpea plants are flowering and fruiting, and it specializes in sucking the small 2-3 day old pods, which

shriveled and are lost to the plant. The eggs are laid in short rows or scattered, and are mostly found on leguminous trees and weeds, with only a few on cowpea plants. *Riptortus dentipes* undergoes five nymphal instars before maturing as an adult. The cylindrical nymphs and adults are generally found lying on foliage or feeding on new shoots and green pods (Oparaeke *et al.*, 2000).

The body, specifically the abdomen, is flat and slender. Two ocelli are present between the two compound eyes. The pronotum is large, with two prominent lateral spines that are probably utilized for defence (Aina, 2007).

### 2.5.5 *Nezara viridula*

*Nezara viridula*, also known as the green stink bug, is found all over the tropics and subtropics. It lays its eggs in batches of 30 to 80 eggs on the underside of leaves and can complete its life cycle in 30-60 days. In warm regions, the green stink bug can have up to four generations every year. Nymphs have five instars and are gleaming with sparkling spots, while adults are green and have a five-sided form (Singh *et al.*, 1979).

It has piercing and sucking mouthparts with which it feeds on growing shoots and developing fruits, and thus lowering the market value of the crop in the process. Damage results from the loss of plant fluid, injection of digestive enzymes, abortion of fruits, and damaged seed. Stink bug feeding often predisposes the plant to infection by pathogenic and decay organisms. Various fungi and bacteria can infect the pod at the feeding site resulting in localized or general pod decay. Seed damaged by stink bug feeding may stop growing resulting in small, wrinkled seed that may remain green (Yeargan, 1977).

### 2.6 Storage insect pests of cowpea

Dry grain legumes in storage face a significant threat from pests. They are mostly affected by storage insect pests, which produce significant economic losses. The most prominent storage insect pests that cause considerable losses in food legumes, including *Vigna* species, are *Callosobruchus maculatus*, *C. chinensis*, *C. analis*, *Acanthoscelides obtectus*, *Bruchus*

*incarnates*, *B. rufimanus*, *B. dentipes*, *B. quinqueguttatus*, *B. emarginatus*, *B. ervi*, *B. lentis* and *B. pisorum* (Schoonhoven, 1978; Jones, 1999; Stejskal *et al.*, 2014 ;Keneni *et al.*, 2011), Because of its propensity to infest the grains from the field, *Callosobruchus* species is well established as the most important pest among these storage insect pests of cowpea (Stejskal *et al.*, 2014). Due to the kind of damage and economic losses it causes to grain legumes, particularly cowpea, *C. maculatus* stands out among the species.

### 2.6.1 *Callosobruchus* species

*Callosobruchus chinensis* is a harmful insect pest of pulses. It is known to be prolific and fast-breeding, and it can swiftly reduce the quantity of stored grains as well as reduce their nutritional value. The distribution of this insect is worldwide; however, it is more common in tropical and sub-tropical areas (Mensah, 1986). Bawa *et al.* (2017) reported the presence and distribution of *C. chinensis* in four major agricultural produce markets in the central region, Ghana.

*C. chinensis* is not only considered to be a destructive insect on pulses but also causing severe damage to the extent of 93.33% in different pulse crops (Parsai *et al.*, 1989).

### *Callosobruchus analis*

In four major agricultural produce markets in the Central Region of Ghana, *Callosobruchus analis* (20%) was next to *C. maculatus* (30%) in terms of abundance, specifically, in Cape Coast, Kotokroba market (Bawa *et al.*, 2017). This species has its inner carina of hind femur appearing numerous and irregularly spaced small denticles along its proximal two-thirds. They have their inner tooth rather shorter than or equal to their outer tooth with their pronotum appearing with uniformly reddish-brown cuticle, and with sparse golden setae with the exception on the basal median gibbosities, which extend only slightly beyond the posterior margin with sparse white setae. Their eyes are less deeply emarginated but rather flattened and less prominent with the male genitalia having median lobe without sclerotized areas near its middle (Fatima *et al.*, 2016).

*Callosobruchus analis* (F.) causes considerable loss in quality and quantity of stored products and is cosmopolitan (Duraimurugan *et al.*, 2011).

### *Callosobruchus maculatus*

Several species of the Bruchidae family have been reported to attack cowpea. This bug spends nearly its entire lifetime in a single grain. There are around 1,350 species in this family that have been identified around the world (Tuda *et al.*, 2006; Fatima *et al.*, 2016). Due to the invasion of multiple pests, the full production potential of cowpea is rarely fulfilled, with bruchid infestation accounting for the majority of total seed loss after harvest. Bruchids cause both quantitative and qualitative damage to seeds by consuming them and contaminating them with excrement and debris. The infested seeds have circular holes in them, resulting in a decrease of quality and viability. A single larva in a pulse grain can cause weight loss of 8 to 22 percent, and they can destroy all cowpea grains by generating up to 100 percent losses after a few months of storage (Cherry *et al.*, 2007).

Those with an African host range are the most frequent and important, with *Callosobruchus maculatus* being the most important due to the harm it causes to cowpea grains (Beck and Blumer, 2014; Devi and Devi, 2014; Fatima *et al.*, 2016). Various species of the genus *Callosobruchus*, the most prevalent of which are *Callosobruchus maculatus* and *Callosobruchus chinensis*, are the primary storage pests of cowpea in Ghana and many regions of Africa (Singh & Jackai, 1985).

The cowpea weevil, or cowpea seed beetle, also known as *Callosobruchus maculatus*, is not a true weevil, however, it is one of the most widespread species of bruchid distributed throughout the tropics and sub-tropics (CABI, 2004). This natural and common pest of stored legumes has a global distribution, occurring on major land masses with the exception of Antarctica and New Zealand.

At least twenty species of the genus *Callosobruchus* are found primarily in tropical and subtropical regions of the world, with origins primarily in Africa and Asia (Tuda *et al.*, 2005).

Among the storage insect pests of cowpea, it is well established that *Callosobruchus* species is the most important pest due to its ability to infest the grains from the field (Stejskal *et al.*, 2014). *Callosobruchus maculatus* is the outstanding one among the species due to the nature of its damage and economic losses it causes to grain legumes especially cowpea (*Vigna unguiculata*). The life cycle of *C. maculatus* consists of an egg, four larval instars, a pupa and adult. According to Gomez (2003), the typical period for each stage at 25 °C is as follows: an adult female lays an egg on the surface of a bean. In laboratory conditions, a single female adult bruchid will lay up to 100 eggs in her lifetime by dispersing them on the grain (Beck and Blumer, 2007). Individual eggs are oval or spindle shaped and firmly glued to the surface of the bean. The egg hatches about 4-8 days later.

After hatching, the tiny grub-like larva emerges, burrowing into the bean through the bottom of its egg shell (Raina, 1970). Inside the bean, the larva feeds on the endosperm and the embryo of the bean, whilst undergoing a series of moults through its larval instars. This takes about 22 days. The larva chews close to the surface and leaves an uneaten thin coating that acts as a "window." The fourth larval instar burrows into a position just under the seed coat prior to pupation. Pupation results in the breakdown of larval structures and the development of adult structures. The adult stays in the cell for several days after pupation before pushing or chewing out the window with its mandibles. By chewing and extracting a circular piece of the seed coat to create a round opening, the adult emerges.

The total developmental period takes approximately 30 days. It may take the beetle 24 to 36 hours to fully mature after it emerges as an adult, with a lifespan of between 10 and 14 days. *Callosobruchus maculatus* can withstand a wide range of humidity and temperature, making it adaptable to a variety of climates. Its developmental period is affected by factors such as humidity, temperature, legume type, crowding, and population inbreeding (Fox and Reed, 2011; Beck and Blumer, 2014). Adult sexes can be easily distinguished with the naked eye based on their morphological differences. The colouration on the plate covering the end of the abdomen is their

most distinguishing feature. Adult females have dark stripes on both sides of their posterior dorsal abdomen, which adult males lack (Beck and Blumer, 2007, 2014). The females are often larger and darker than the males, who are smaller and brown in colour.

Bean beetles have two adult types (morphs), one that is sedentary (flightless) and the other that is dispersal (flying). The dispersal morph is caused by density-dependent microhabitat temperature rises (Beck and Blumer, 2014) and is triggered by high larval density in stored beans or laboratory cultures (Utida 1956, 1972). Individuals may migrate to fresh, better-quality environments after the dispersal morph is induced. Compared to the sedentary morph, the dispersal morph has a slightly longer adult lifespan and significantly reduced fecundity (Utida 1956, 1972). The sexes are highly dimorphic and easily distinguishable in the sedentary form, but in the dispersal form, sex distinctions are very subtle. Adults of *C. maculatus* are normally found in flowers in the early part of the season. At the end of the rainy season, they can be seen colonizing cowpeas, continuing to develop and multiply in the stores (Gómez, 2004).

Bean beetles are herbivores that have specialized in seed consumption in terms of ecology. They form part of food chains since parasitoid wasp species feed on their eggs and larvae (Boeke *et al.*, 2003). Adults may also be prey for birds, reptiles and amphibians, and hence, they serve as sources of food for other organisms in the food chain (Beck and Blumer, 2014).

The cowpea weevil, *C. maculatus* Fab. (Coleoptera: Bruchidae) is a major pest of economic importance to leguminous grains (Akash *et al.*, 2015). During storage, the pest can cause up to 100% damage to legume seeds (Gbaye *et al.*, 2011). It attacks a variety of bean species, as well as other leguminous crops like *Voandzeia subterranean* (Bambara nuts) and *Cajanus cajan* (Pigeon peas).

Eggs are laid on maturing pods in the field, which is where the infestation usually starts (Prevett, 1961; Messina, 1984; Fitzner *et al.*, 1985). Infestation may begin in the pods prior to harvest and spread to storage, resulting in significant losses. The type of storage structure used and the variety

of seed used have a significant impact on the level of infestation in storage (Ojimelukwe *et al.*, 1999). Seed storage structures that keep high levels of moisture in the seeds are more likely to be infested (Singh, 1999). The pest's ability to infest the pods decreases as they dry. As a result, dry seeds in their pods are relatively resistant to attack, whereas threshed seeds are vulnerable to attack throughout storage. Infestation levels in local stores are also influenced by storage temperature (Singh, 1997).

Due to the damaging effects the pulse beetle has on cowpea grains, it is essential that strategies are put in place to decrease, or possibly destroy the effects they cause on cowpeas. Since legumes are the cheapest and richest source of plant protein for humans and livestock, and are sometimes referred to as "poor man's meat," pest control is critical (Singh and Pandey, 2001). On the field and storage levels, there are some management strategies that have been put in place for *C. maculatus*. These include biological, mechanical, physical, chemical and cultural controls, host plant resistance and integrated control measures.

## 2.7 Phytochemicals

Plants produce diverse assortment of compounds and majority of them do not participate directly in growth and development. Phytochemicals, also known as secondary metabolites, are found in plants and are distributed differently. Since the 1850s, phytochemicals have been widely studied for their chemical qualities, despite the complexity of their chemical structures and metabolic routes. The current focus on the search for new medications, antibiotics, insecticides, herbicides, and behaviour-modifying chemicals is spurred by recognition of the biological activities of a vast number of phytochemicals. Many of these chemicals have been proven to play a crucial adaptive role in herbivory defence (Croteau *et al.*, 2000).

### 2.7.1 Flavonoids

Flavonoids are plant metabolites that are responsible for the majority of the plant pigments that give flowers their colour. When there are high concentrations of flavonoids and phenolics present,

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as well as some important structural features, such as the arrangement and number of hydroxyl groups, the presence of electron-donating /accepting substituents on the ring, and the extent of structural conjugation of the ring, antioxidant activity of plant extracts tends to increase (Middleton *et al.*, 2000). Plant phenols have gained a lot of attention recently because of their usefulness in preventing oxidative stress-related diseases including cancer (Amadi *et al.*, 2016).



**3.0 MATERIALS AND METHODS**

**3.1 Experimental site**

The studies were carried out at two levels- Field and laboratory. Laboratory studies was conducted at the insectary of the Department of Animal Biology and Conservation Science, University of Ghana, Legon and field studies were carried out in both the major (March- May 2012) and the minor (November- January 2021) seasons at the University of Ghana Experimental farm, Legon in Accra.

**3.2 Experimental or biological material**

Five cowpea varieties were acquired from Professor Isaac K. Asante, a plant breeder of the Department of Plant and Environmental Biology of the University of Ghana, Legon for the experiment. The varieties were “Asontem”, “Golinga”, Kirkhouse, “Padi Tuya” and “Wang Kae”.

**3.3 Field set up**

**3.3.1 Design and layout**



Plate 1: Field layout in a Randomised Complete Block Design

### 3.3.2 Agronomic practices

The field was ploughed to a depth of 20 cm and later harrowed after two weeks. Lining and pegging were done on a plot size of 2 m x 2.1 m. Three cowpea seeds were sown per hill at a spacing of 70 cm between rows and 50 cm between plants. Thinning was done to allow for one seedling per stand.

### 3.7.1 Field Parameters

Six middle plants (Plate 1) were selected from each plot and tagged, and the following parameters were recorded on each of them at weekly intervals for six weeks.

**a. Plant Height:** The plant height was measured using a graduated meter rule from the soil to the last terminal leaf of the plant. The mean height of the six plants was recorded to represent each treatment.

**b. Stem Girth:** Stem girth was measured using a digital calliper at 5 cm above ground level. The averages of the stem girth measurements were determined and recorded.

**c. Number of leaves per plant:** Number of leaves per plant was counted and the average was recorded after counting all the 6 middle plants.

### 3.7.2 Yield Parameters

After harvesting, the following yield parameters were taken on the pods that were harvested from the field.

**a. Number of pods per plant:** The total number of dried pods were harvested on each of the 6 middle plants.

**b. Weight of pod per plant:** The total weight of pods harvested from the 6 middle plants was determined. The average of the weights determined from the six plants was recorded as weight of pods per plant.

**c. Pod length:** Ten out of the total number of pods that were harvested from the 6 middle plants on each plot were measured individually and their average length taken as pod length per plot. These measurements were done in the laboratory.

**d. Number of seeds per pod:** The number of seeds per pod was counted from the pods of the 6 middle plants and their average number recorded as the number of seeds per pod.

**e. Seed weight per plant:** The pods harvested from each plot were depodded and the seeds weighed using an electronic balance. The average obtained is recorded as seed weight per plant. The total number of seeds that were collected from the 6 middle plants were added together and weighed in order to get the seed weight per plant for the individual treatments.

**f. Number of loci per pod:** Ten pods from each plot were randomly selected and their locus counted, the average of the locus obtained were recorded as the number of loci per pod.

**g. Mean 100-seed weight:** Hundred seeds from each treatment were randomly picked and weighed. This was replicated five times and the average seed weight determined. The average weight of 5 counts was then taken as the weight of hundred seeds for each treatment.

### 3.7.3 Insect sampling

Insect sampling commenced two weeks after planting and was carried out during the vegetative growth, reproductive growth, and pod maturity stages. Sampling was done early in the morning between 6:30 am and 8:30am and collection was done weekly.

Six middle plants of each plot were tagged for insect data collection. Insect sampling was done by visual examination and the use of yellow pan traps. Insects collected on the field which were not readily identified were preserved in vials containing 70% ethanol and brought to the laboratory for identification using insect identification keys. Insect species collected were counted and recorded.

### 3.4 Laboratory set up

#### 3.4.1. Laboratory design and layout

The design for the experiment was Completely Randomised Block design (CRBD) with five treatments and four replicates.

#### 3.4.2 *Callosobruchus maculatus* culture

The initial stock culture of *Callosobruchus maculatus* used for the experiment was obtained from infested cowpea stored at the insectary of the Department of Animal Biology and Conservation Science, University of Ghana, Legon. The weevils were retrieved from the infested cowpea through sieving. The grains were sieved to get rid of dirt and broken particles and sterilized in an oven at 60°C for 3 hours to kill any insect eggs which might have been present in the grains. Glass jars used were sterilized by heating at 60°C for 3 hours. Two hundred adults *Callosobruchus maculatus* were introduced into different 1 L glass jars with 1.2 kg of cowpea and were replicated five times. This was followed by covering the glass jars with muslin cloth to prevent possible re-infestation. The jars were placed on inverted petri dishes in industrial oil on shallow trays to keep out other unwanted insects. The insects were allowed to oviposit for ten (10) days in the laboratory after which they were retrieved by sieving. The insect cultures were kept under a temperature of chamber at 28±1°C, relative humidity (r.h.) of 65 – 75% and photoperiod of LD 16:8 (hours light: dark) (Owusu, 2001)

After 3 weeks of the oviposition period, the F1 progeny were collected by sieving. The F1 adult weevils that had emerged, which were 0 – 1 week old, were introduced into other glass jars seeded with cowpea for one week by which time they were 1 – 2 weeks old. Subsequent 0-1-week-old adult weevils from the culture jars were transferred into other glass jars seeded with cowpea till they were 1-2 weeks old. This process was repeated several times in order to acquire enough 1–2 weeks old laboratory-reared insects for the studies. This was done because weevil fecundity rates were shown to grow from week one to week three, peaking by week three, and then declining (Dobie, 1974).

### 3.4.3 Repellence of cowpea extracts

The repellent effect of the extracts was tested by using the method adopted by Sheehu (2009). Concentrations (2.0g/mL and 1.0g/mL) of the cowpea extracts were applied to half of a filter paper disc; the other half was treated with 100 % methanol only (which acts as control). The treated filter paper was air-dried for one hour, after which the two were joined together and placed in a petri dish. Five of adult insects were chilled in a refrigerator for 5 minutes and then placed at the middle of the joined filter papers and covered. There were three replicates for each treatment. Adult insects on treated and untreated portions of the filter paper disc were counted after 24 hours and the percentage repellence determined using the formula adopted by Obeng- Ofori *et al.* (1997) and modified by Owusu, 2001).

$$PR = \frac{(N_c - N_t)}{(N_c + N_t)} \times 100$$

Where N<sub>c</sub>: Number of insects on control, N<sub>t</sub>: Number of insects on the extract sides

All negative percentage repellency were treated as zero.



Plate 2: Introduction of extract onto filter paper



Plate 3: Insect repellency test for *C. maculatus*

### 3.4.4 Moisture Content

Prior to the introduction of the weevils, the moisture level of the cowpea varieties was assessed. A moisture meter was used to determine the moisture content of the cowpea varieties using Seedburo 1200D Digital Moisture Tester.

### 3.4.5 Adult Mortality

Adult weevil mortality was assessed 10 days after the weevils were introduced. To calculate adult weevil mortality, the seed lot was sieved, and the number of dead and live weevils counted from each glass jar. The percentage adult weevil mortality was calculated using the formula:

$$\text{Adult weevil mortality} = \frac{\text{Number of dead weevils}}{\text{Total number of weevils}} \times 100$$

### 3.4.6 F<sub>1</sub> Progeny

The insect culture setup was left undisturbed until the first weevils that had finished their development (after 3 weeks) and emerged as adults were observed. The jars were inspected daily to observe the emergence of F<sub>1</sub> adults. Daily counts and removal of the F<sub>1</sub> progeny were done to prevent the F<sub>1</sub> progeny from laying eggs to produce the F<sub>2</sub> generation. The observation and removal of F<sub>1</sub> progeny continued for 56 days by which time they were all expected to have emerged (Abebe *et al.*, 2009).

### 3.4.7 Seed Damage, Weight Loss, and Weight Seed Powder

Four weeks after the weevils were introduced, 200 seeds were randomly selected from each glass jar to determine the number of seeds damaged by weevil feeding (seeds with characteristic emergence holes). Using laboratory sieves, the contents of each glass jar were segregated into seeds, insects, and dust, to assess damaged and undamaged seeds from each jar. Seed damage was calculated using the formula:

Damaged seed (%) = (Number of damaged seeds/ Total number of seeds) x100.

Seed weight loss was determined using the method of FAO (1985), and modified by Udo *et al.* (2004) as follows:

$$\% \text{ Weight loss} = [U_a N - (U+D)] / U_a N \times 100$$

where: U = weight of undamaged fraction in sample,

N = total number of grains in the sample,

$U_a$  = average weight of one undamaged grain

D = weight of damaged fraction in the sample.

Seeds from each glass jar were sieved to collect the dust (frass) produced by the weevils. This was followed by weighing the dust with an electronic balance (Mettler Toledo XS104). This was done from the time the first  $F_1$  generation emerged till the completion of the 56-day observation period.



Plate 4: Set up of *Callosobruchus maculatus* in the cowpea varieties

### 3.4.8 Median Development Period (MDP)

The Median Development Period was calculated as the time (in days) from the middle point of the oviposition period to 50% emergence of the F<sub>1</sub> progeny (Dobie, 1977).

### 3.4.9 Susceptibility Index (SI)

Dobie's Index of Susceptibility (Dobie, 1977) was used to separate the cowpea varieties into various susceptibility groups. This involved the number of F<sub>1</sub> progeny and the length of median development time. The susceptibility index was determined 56 days after infestation according to Dobie (1974) using the formula.:

$$SI = \frac{\text{Log } F}{D} \times 100$$

where SI= Susceptibility Index, Log F = Log of total number of adult weevils emerged and D = median development period (which is calculated as the time in days from the middle of the oviposition period to the emergence of 50% of the F<sub>1</sub> progeny).

The Susceptibility Index ranging from 0 to 11, was used to classify the cowpea varieties; where; 0-3= resistant, 4-7= moderately resistant, 8-10= susceptible and ≥10= highly susceptible (Dobie, 1974).

### 3.5 Phytochemical screening

Phytochemical screening was performed to determine the class of secondary metabolites present in the crude extract of the cowpea varieties. The crude extracts were screened for the presence of alkaloids, tannins, saponins, polyphenols and flavonoids using the protocol of Alidu *et al.*, (2020)

#### 3.5.1 Sample extraction

One hundred grammes (100 g) of cowpea seeds of each of the varieties was weighed and grinded into powder using a blender. Fifty grammes (50 g) of the ground cowpea of each variety was weighed into a conical flask and 100 mL of Acetone added and shaken. The conical flasks and their contents were covered with aluminium foil and left to stand for 48 hrs. The same process was repeated using methanol. After the 48-hour period, the sample in solution was filtered and

concentrated using the rotary evaporator. Concentration of 1g/mL and 2g/mL of each extract was prepared for the bioassay.



Plate 5: Grounded cowpea powder without solvent.



Plate 6: Cowpea powder with solvent .

### 3.5.2 Test for polyphenols

Two (2) mL of the ethanolic (EtOH) extract was transferred into a test tube and 3 drops of 10% aqueous Ferric Chloride ( $\text{FeCl}_3$ ) and 3 drops of Potassium Ferrocyanide ( $\text{K}_4[\text{Fe}(\text{CN})_6]$ ) were added. Formation of a blueish colour indicated the presence of polyphenol

### 3.5.3 Test for flavonoids

Two (2) mL of EtOH extract was transferred into 3 test tubes; A, B and C. Test tube A was used as control. To test tube B, 3 pieces of boiling chips were added, followed by 0.5 mL of conc. Hydrochloric acid (HCl) and observed for any colour changes after warming. 0.5 mL of conc. Hydrochloric acid (HCl) was added to test tube C and warmed for 5 minutes in a water bath. The change of colour in test tubes B and C indicated the presence of flavonoids.

### 3.5.4 Test for alkaloids

Four (4) mL of the 80% ethanolic solution was added to 5 mL of 2M HCl solution. This was stirred, heated and filtered. The filtrate from the extract was then divided equally into three test tubes. 3-5 drops of Dragendorff's reagent were added to one portion of the test solution. To another portion a few drop of Mayer's reagent, and to the remaining test solution, Wagner's reagent. These were then observed for turbidity or colour change.

### 3.5.5 Test for tannins

Five (5) mL of aqueous methanol was added 0.2 g of the extract. The resultant mixture was split between 2 test tubes where one portion served as a blank and the other, freshly prepared  $\text{FeCl}_3$  was added. A greenish or dark blue colouration confirmed the presence of tannins.

### 3.6 Data collection and analysis

Data involving counts and percentages were transformed using square-root and arc sine transformations, respectively (Eziah *et al.*, 2013). This was then subjected to analysis of variance at 5% probability level using GenStat Statistical Package, 12<sup>th</sup> Edition. Where significant differences existed, means were separated using Least Significant Differences (LSD).



## 4.0 RESULTS

### 4.1 Field Experiment

#### 4.1.1 Field assessment of insect pest infestation at different cowpea developmental stages.

The different insects that were collected from the selected cowpea varieties are listed in Table 1 below. In all, ten (10) insect species were collected in the minor season and ten (10) insect species were collected in the major season.

Table 1: List of insects collected on the field for the cowpea varieties at the different developmental stages

Insect	Common name	Order	Family	SEASON	
				Minor	Major
<i>Aphis craccivora</i>	Cowpea aphid	Homoptera	Aphididae	+	+
<i>Cydia ptychora</i>	Cowpea pod borer	Lepidoptera	Olethreutidae	-	+
<i>Empoasca sp</i>	Cowpea leafhopper	Homoptera	Cicadellidae	+	-
<i>Lampides boeticus</i>	Pea blue	Lepidoptera	Lycaenidae	+	+
<i>Maruca vitrata</i>	Legume pod borer	Lepidoptera	Pyralidae	+	+
<i>Megalurothrips sjostedti</i>	Flower bud thrips	Thysanoptera	Thripidae	+	+
<i>Mylabris sp.</i>	Flower beetle	Coleoptera	Meloidae	-	+
<i>Nezara viridula</i>	Green sting bug	Heteroptera	Pentatomidae	+	+
<i>Ootheca mutabilis</i>	Cowpea leaf beetle	Coleoptera	Chrysomelidae	+	-
<i>Ophiomyia phaseoli</i>	Bean fly	Diptera	Agromyzidae	+	-
<i>Podagrica uniformis</i>	Okra flea beetle	Coleoptera	Halticidae	-	+
<i>Riptortus dentipes</i>	Pod sucking bug	Heteroptera	Alydidae	+	+
<i>Zonocerus variegatus</i>	Variegated grasshopper	Orthoptera	Pyrgomorphidae	+	+

NB: Present (+) and Absent (-)

These insects were collected from the cowpea varieties at different growth stages of the plant.

*Aphis craccivora* was found in all the cowpea varieties in both seasons, with ‘‘Padi Tuya’’ recording the highest and ‘‘Golinga’’ recording the least in the minor season (Table 2). In the major season, ‘‘Golinga’’ recorded the highest number of *Aphis craccivora* and ‘‘Asontem’’ recorded the least number (Tables 2). At probability  $P < 0.05$ , there was significant difference in the mean *Aphis craccivora* infestation between ‘‘Padi Tuya’’ and ‘‘Golinga’’ in the minor season, but there was no significant difference in the major season.

Table 2: Mean number of insects recorded at the vegetative growth stage in the minor season.

Variety	<i>Zonocerus variegatus</i>	<i>Ophiomyia phaseoli</i>	<i>Aphis craccivora</i>	<i>Empoasca sp.</i>	<i>Ootheca mutabilis</i>
<i>Asontem</i>	1.3 (1.1) $\pm$ 0.1 <sup>a</sup>	1.5 (1.2) $\pm$ 0.2 <sup>a</sup>	0.8 (1.3) $\pm$ 0.1 <sup>a</sup>	4.5 (2.1) $\pm$ 0.2 <sup>b</sup>	7.8 (2.8) $\pm$ 0.1 <sup>a</sup>
<i>Golinga</i>	1.3 (1.1) $\pm$ 0.1 <sup>a</sup>	2.8 (1.6) $\pm$ 0.2 <sup>b</sup>	0.3 (1.1) $\pm$ 0.1 <sup>a</sup>	2.0 (1.4) $\pm$ 0.0 <sup>a</sup>	10.8 (3.3) $\pm$ 0.1 <sup>a</sup>
<i>Kirkhouse</i>	2.0 (1.4) $\pm$ 0.2 <sup>a</sup>	2.5 (1.5) $\pm$ 0.3 <sup>b</sup>	1.0 (1.4) $\pm$ 0.2 <sup>a</sup>	7.0 (2.6) $\pm$ 0.1 <sup>c</sup>	6.8 (2.6) $\pm$ 0.1 <sup>a</sup>
<i>Padi Tuya</i>	2.5 (1.5) $\pm$ 0.3 <sup>b</sup>	1.0 (1.0) $\pm$ 0.0 <sup>a</sup>	2.3 (1.8) $\pm$ 0.1 <sup>b</sup>	7.8 (2.8) $\pm$ 0.1 <sup>c</sup>	8.5 (2.9) $\pm$ 0.1 <sup>a</sup>
<i>Wang Kae</i>	1.5 (1.2) $\pm$ 0.1 <sup>a</sup>	1.3 (1.1) $\pm$ 0.1 <sup>a</sup>	0.5 (1.2) $\pm$ 0.1 <sup>a</sup>	8.3 (2.9) $\pm$ 0.1 <sup>c</sup>	7.8 (2.8) $\pm$ 0.1 <sup>a</sup>
p value	0.374	0.111	0.004	0.001	0.005

Means within each column followed by the same letter are not significantly different ( $P > 0.05$ ). Values in brackets are log transformed means of the respective means.



Table 3: Mean number of insects recorded at the vegetative growth stage in the major season

Variety	<i>Aphis craccivora</i>	<i>Podagrica uniformis</i>
<i>Asontem</i>	3.5 (1.89) ± 0.6 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
<i>Golinga</i>	21.0 (4.0) ± 1.4 <sup>c</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>
<i>Kirkhouse</i>	4.5 (2.0) ± 0.7 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>
<i>Padi Tuya</i>	18.5 (4.0) ± 1.1 <sup>c</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>
<i>Wang Kae</i>	17.8 (2.9) ± 1.9 <sup>c</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
p value	0.653	0.415

Means within columns followed by the same letter are not significantly different ( $P > 0.05$ ). Values in brackets are log transformed means of the respective means.

*Megalurothrips sjostedti* and *Zonocerus variegatus* were recorded in both seasons at the reproductive growth stage. ‘Wang Kae’ recorded the highest number of *M. sjostedti* in the minor season, while ‘Golinga’ recorded the least number of *M. sjostedti*. ‘Padi Tuya’ recorded the highest number of *Z. variegatus* in the minor season, while ‘Golinga’ recorded the least number (Table 4). In the major season, ‘Padi Tuya’ recorded the highest number of *M. sjostedti*, while ‘Golinga’ recorded the least number. ‘Asontem’ recorded the highest number of *Z. variegatus*, while ‘Padi Tuya’ recorded no *Z. variegatus* (Table 5). Five insect species were encountered in the major season, while three species were encountered in the minor season during the reproductive stages.



Table 4: Mean number of insects recorded at the reproductive growth (flowering) stage in the minor season.

Variety	<i>Zonocerus variegatus</i>	<i>Ophiomyia phaseoli</i>	<i>Megalurothrips sjostedti</i>
<i>Asontem</i>	1.0 (1.4) ± 0.2 <sup>a</sup>	2.0 (1.7) ± 0.1 <sup>b, c</sup>	2.3 (1.7) ± 0.4 <sup>b</sup>
<i>Golinga</i>	0.3 (1.1) ± 0.1 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	0.8 (1.3) ± 0.2 <sup>a</sup>
<i>Kirkhouse</i>	1.3 (1.5) ± 0.1 <sup>b</sup>	1.8 (1.6) ± 0.1 <sup>b</sup>	2.0 (1.6) ± 0.4 <sup>b</sup>
<i>Padi Tuya</i>	2.3 (1.8) ± 0.1 <sup>b</sup>	2.8 (1.9) ± 0.1 <sup>c</sup>	6.0 (2.5) ± 0.4 <sup>c</sup>
<i>Wang Kae</i>	1.5 (1.6) ± 0.1 <sup>b</sup>	2.0 (1.7) ± 0.0 <sup>b, c</sup>	7.8 (2.8) ± 0.5 <sup>c</sup>
p value	0.021	0.001	0.079

Means within columns followed by the same letter are not significantly different ( $P > 0.05$ ). Values in brackets are log transformed means of the respective means.



Table 5: Mean number of insects recorded at the reproductive growth (flowering) stage in the major season

Variety	<i>Megalurothrips sjostedti</i>	<i>Mylabris</i> sp.	<i>Cydia ptychora</i>	<i>Zonocerus variegatus</i>	<i>Aphis craccivora</i>
<i>Asontem</i>	7.0 (2.7) ± 0.4 <sup>c</sup>	5.0 (2.3) ± 0.5 <sup>b</sup>	0.2 (1.1) ± 0.1 <sup>a</sup>	1.5 (1.5) ± 0.2 <sup>b</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
<i>Golinga</i>	0.2 (1.1) ± 0.1 <sup>a</sup>	2.5 (1.7) ± 0.4 <sup>b</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
<i>Kirkhouse</i>	3.8 (2.1) ± 0.4 <sup>b</sup>	0.8 (1.3) ± 0.1 <sup>a</sup>	2.0 (1.7) ± 0.2 <sup>b</sup>	0.8 (1.3) ± 0.2 <sup>a,b</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
<i>Padi Tuya</i>	7.5 (2.8) ± 0.5 <sup>c</sup>	5.5 (2.5) ± 0.3 <sup>c</sup>	1.0 (1.4) ± 0.2 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>
<i>Wang Kae</i>	6.8 (2.4) ± 0.8 <sup>b</sup>	1.0 (1.4) ± 0.2 <sup>a</sup>	1.3 (1.4) ± 0.3 <sup>a</sup>	0.8 (1.3) ± 0.1 <sup>a,b</sup>	0.8 (1.3) ± 0.2 <sup>a</sup>
p value	0.375	0.105	0.124	0.039	0.102

Means within columns followed by the same letter are not significantly different (P > 0.05). Values in brackets are log transformed means of the respective means.



Insect pests such as *Maruca vitrata*, *Nezara viridula*, *Lampides boeticus*, *Riptortus dentipes* and *Zonocerus variegatus* were encountered at the pod maturity stage in both seasons. ‘‘Padi Tuya’’ recorded the highest number of *M. vitrata*, *Nezara viridula* and *R. dentipes* in the minor season, while ‘‘Golinga’’ recorded the least number of *M. vitrata*, *L. boeticus* and *N. viridula* (Table 6). In the major season, ‘‘Kirkhouse’’ recorded the highest number of *M. vitrata* and *N. viridula*, while ‘‘Golinga’’ and ‘‘Wang Kae’’ recorded the least number of *M. vitrata* and *N. viridula*, respectively (Table 7).

Table 6: Mean number of insects recorded at the pod maturity (podding) stage in the minor season

Variety	<i>Maruca vitrata</i>	<i>Nezara viridula</i>	<i>Lampides boeticus</i>	<i>Riptortus dentipes</i>	<i>Zonocerus variegatus</i>
<i>Asontem</i>	2.3(1.8) ± 0.1 <sup>b</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	0.8 (1.3) ± 0.3 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	3.0 (1.8) ± 0.5 <sup>b</sup>
<i>Golinga</i>	0.8 (1.3) ± 0.1 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	0.8 (1.3) ± 0.1 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>
<i>Kirkhouse</i>	1.3 (1.5) ± 0.2 <sup>a</sup>	0.8 (1.3) ± 0.2 <sup>ab</sup>	4.0 (2.2) ± 0.2 <sup>b</sup>	1.0 (1.4) ± 0.2 <sup>a</sup>	2.0 (1.6) ± 0.4 <sup>b</sup>
<i>Padi Tuya</i>	4.0 (2.2) ± 0.1 <sup>c</sup>	1.8 (1.6) ± 0.1 <sup>b</sup>	4.0 (2.2) ± 0.3 <sup>b</sup>	3.0 (2.0) ± 0.1 <sup>b</sup>	5.5 (2.1) ± 0.8 <sup>b</sup>
<i>Wang Kae</i>	1.0 (1.4) ± 0.2 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>	3.0 (1.9) ± 0.4 <sup>b</sup>	2.8 (1.8) ± 0.5 <sup>b</sup>	0.8 (1.3) ± 0.2 <sup>a</sup>
p value	0.001	0.043	0.096	0.076	0.686

Means within columns followed by the same letter are not significantly different (P> 0.05). Values in brackets are log transformed means of the respective means.



Table 7: Mean number of insects recorded at the pod maturity (podding) stage in the major season

Variety	<i>Maruca vitrata</i>	<i>Nezara viridula</i>	<i>Lampides boeticus</i>	<i>Riptortus dentipes</i>	<i>Zonocerus variegatus</i>
<i>Asontem</i>	1.8 (1.6) ± 0.2 <sup>b</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	4.2 (1.9) ± 0.7 <sup>b</sup>
<i>Golinga</i>	1.0 (1.4) ± 0.2 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>
<i>Kirkhouse</i>	2.5 (1.8) ± 0.3 <sup>b</sup>	0.8 (1.3) ± 0.2 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	1.0 (1.4) ± 0.2 <sup>a</sup>	2.0 (1.6) ± 0.4 <sup>b</sup>
<i>Padi Tuya</i>	1.3 (1.4) ± 0.3 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>	0.0 (1.0) ± 0.0 <sup>a</sup>	1.5 (1.5) ± 0.3 <sup>b</sup>	5.2 (2.0) ± 0.9 <sup>b</sup>
<i>Wang Kae</i>	0.0 (1.0) ± 0.0 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>	0.3 (1.1) ± 0.1 <sup>a</sup>	0.5 (1.2) ± 0.1 <sup>a</sup>	0.8 (1.3) ± 0.2 <sup>a</sup>
p value	0.107	0.490	0.445	0.239	0.742

Means within columns with the same letter are not significantly different (P> 0.05). Values in brackets are log transformed means of the respective means.

#### 4.1.2 Field assessment of yield of cowpea varieties.

Insect pest infestation affected the yield of cowpea varieties, especially, infestation by *Aphis craccivora*, *Megalurothrips sjostedti* and *Maruca vitrata*, which were the most destructive among the insect pests encountered on the field. Correlation between the insect infestations and the total yield of the cowpea varieties in the field was determined (Figs. 1-3). *Aphis craccivora* infestation was negatively correlated with total yield ( $r = -0.2368$ ,  $P > 0.05$ ) in the major season (Fig. 1). Meanwhile, *Megalurothrips sjostedti* infestation was negatively correlated with the total yield ( $r = -0.0784$ ,  $P > 0.005$ ) in the major season and was also negatively correlated with the total yield ( $r = -0.4232$ ,  $P > 0.01$ ) in the minor season (Fig. 2). *Maruca vitrata* infestation was positively correlated with the total yield ( $r = 0.0636$ ),  $P > 0.05$ ) in the major season, while was negatively correlated with the total yield ( $r = -0.3767$ ,  $P > 0.01$ ) in the minor season (Fig. 3).

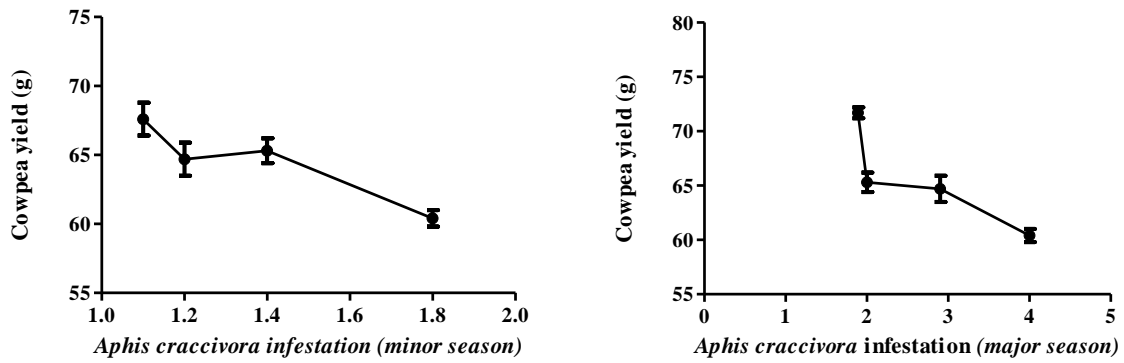


Figure 1: Correlation between cowpea yield and *Aphis craccivora* infestation

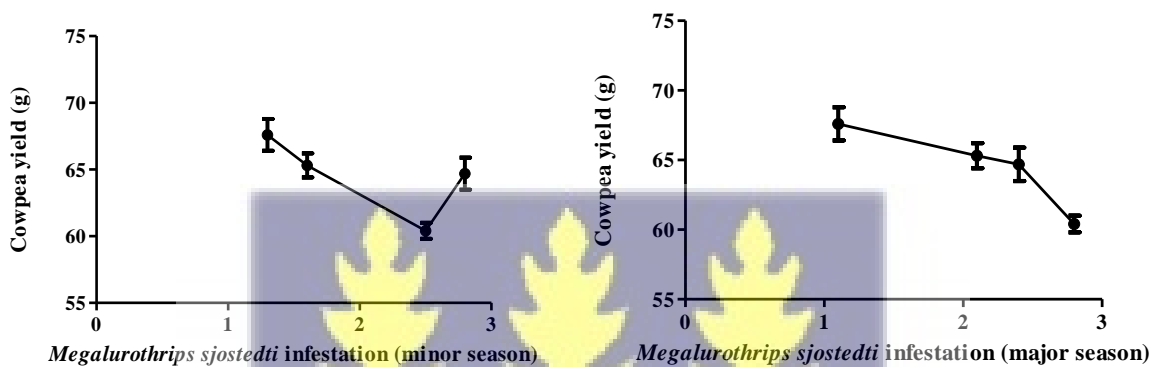


Figure 2: Correlation between cowpea yield and *Megalurothrips sjostedti* infestation

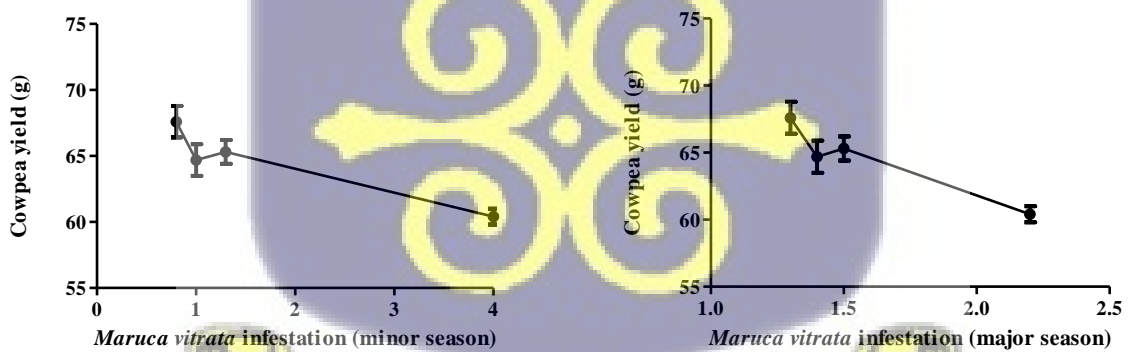


Figure 3: Correlation between cowpea yield and *Maruca vitrata* infestation.

The mean number of pods per plant and mean yield of the cowpea varieties were recorded for both the minor and the major seasons. In the minor season, ‘Golinga’ recorded the highest mean number of pods per plant, while ‘Padi Tuya’ recorded the least mean number

of pods per plant. Meanwhile, 'Asontem' recorded the highest mean yield of 71.7 g in the minor season, while 'Padi Tuya' recorded the least mean yield of 60.4 g (Table 8).

In the major season, 'Wang Kae' recorded the highest mean number of pods per plant, while 'Padi Tuya' recorded the least mean number of pods per plant. Meanwhile, 'Asontem' recorded the highest mean total yield of 74.1g, while 'Padi Tuya' recorded the least mean total yield of 59.2 g (Table 9).



Table 8: Yield assessment of the cowpea varieties in the minor season

Variety	Pods per plants	Weight of pods per plant	Length of pod (mm)	No. of seeds/pod	No. of locus per pod	Seed weight per plant	100- seed weight	Yield (g)
Mean ± S.E.								
<i>Asontem</i>	5.53 ± 0.7 <sup>c</sup>	11.1 ± 1.4 <sup>c</sup>	14.78 ± 0.5 <sup>d</sup>	13.35 ± 0.6 <sup>c</sup>	14.35 ± 0.5 <sup>b</sup>	11.73 ± 1.8 <sup>a</sup>	16.9 ± 0.7 <sup>b</sup>	71.7 ± 0.5 <sup>c</sup>
<i>Golinga</i>	8.43 ± 2.3 <sup>d</sup>	16.9 ± 4.6 <sup>e</sup>	11.80 ± 0.2 <sup>a,b</sup>	11.24 ± 0.4 <sup>b</sup>	12.34 ± 0.4 <sup>a</sup>	8.70 ± 2.5 <sup>a</sup>	10.2 ± 0.4 <sup>a</sup>	67.6 ± 1.2 <sup>b</sup>
<i>Kirkhouse</i>	4.82 ± 0.3 <sup>b</sup>	9.6 ± 0.5 <sup>b</sup>	12.79 ± 0.5 <sup>b,c</sup>	11.89 ± 0.3 <sup>b</sup>	12.88 ± 0.2 <sup>a</sup>	12.04 ± 1.1 <sup>a</sup>	21.5 ± 0.5 <sup>c</sup>	65.3 ± 0.9 <sup>b</sup>
<i>Padi Tuya</i>	3.96 ± 0.3 <sup>a</sup>	8.0 ± 0.7 <sup>a</sup>	11.21 ± 0.6 <sup>a</sup>	9.75 ± 0.7 <sup>a</sup>	11.69 ± 0.7 <sup>a</sup>	9.69 ± 1.0 <sup>a</sup>	25.5 ± 0.6 <sup>d</sup>	60.4 ± 0.6 <sup>a</sup>
<i>Wang Kae</i>	7.57 ± 1.2 <sup>d</sup>	15.1 ± 2.4 <sup>d</sup>	13.43 ± 0.6 <sup>c,d</sup>	11.07 ± 0.1 <sup>a,b</sup>	12.62 ± 0.1 <sup>a</sup>	22.87 ± 3.5 <sup>b</sup>	28.3 ± 0.4 <sup>e</sup>	64.7 ± 1.2 <sup>b</sup>
p value	0.083	0.087	0.003	0.002	0.016	0.005	0.001	0.001

Means within columns with the same letter are not significantly different ( $p > 0.05$ ), while different letters indicate significance between values. Values in brackets are log transformed means of the respective mean.

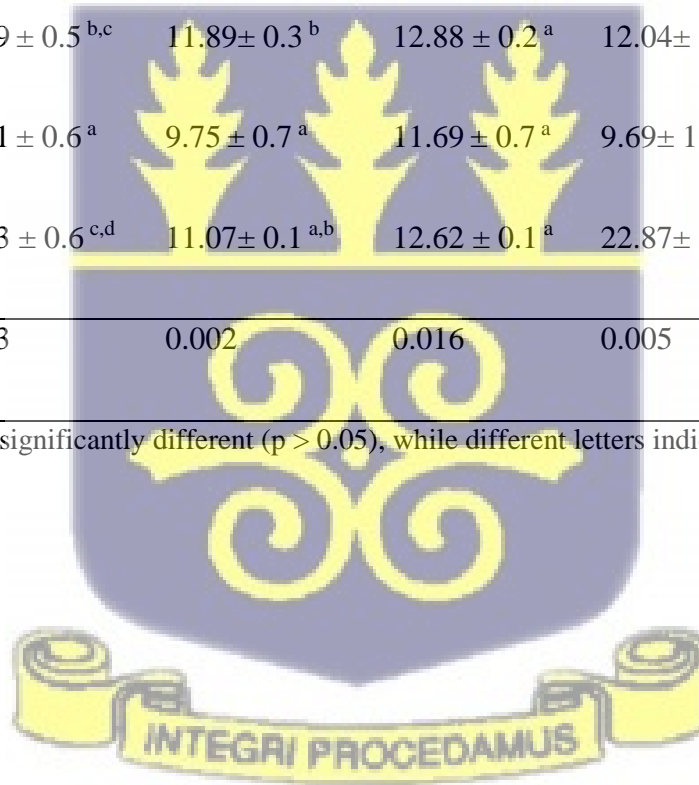
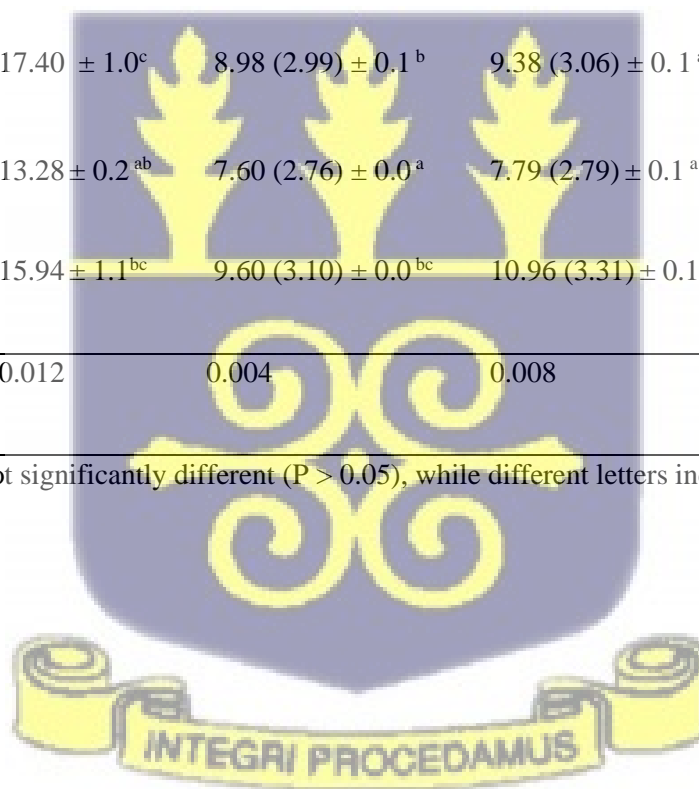


Table 9: Yield assessment of the cowpea varieties in the major season

Variety	No. pods per plant	Weight of pods per plant	Length of pod (cm)	No. of seeds/pod	No. of locus/pod	Seed weight per plant	100-seed weight	Yield (g)
Mean Yield± S.E.								
<i>Asontem</i>	9.44 ± 0.2 <sup>a</sup>	20.73 ± 3.7 <sup>bc</sup>	13.33 ± 1.1 <sup>ab</sup>	10.19 (3.19) ± 0.1 <sup>bc</sup>	10.57 (2.79) ± 0.1 <sup>b</sup>	11.32 ± 1.5 <sup>b</sup>	15.74 ± 0.1 <sup>b</sup>	74.1 ± 0.9 <sup>a</sup>
<i>Golinga</i>	10.00 ± 0.2 <sup>b</sup>	11.58 ± 1.5 <sup>a</sup>	12.93 ± 0.4 <sup>a</sup>	10.42 (3.23) ± 0.1 <sup>c</sup>	10.90 (3.30) ± 0.1 <sup>b</sup>	8.62 ± 1.0 <sup>a</sup>	9.12 ± 0.2 <sup>a</sup>	69.5 ± 0.5 <sup>b</sup>
<i>Kirkhouse</i>	8.86 ± 0.2 <sup>a</sup>	15.56 ± 2.2 <sup>ab</sup>	17.40 ± 1.0 <sup>c</sup>	8.98 (2.99) ± 0.1 <sup>b</sup>	9.38 (3.06) ± 0.1 <sup>ab</sup>	12.78 ± 0.5 <sup>bc</sup>	20.94 ± 1.0 <sup>c</sup>	66.6 ± 0.5 <sup>c</sup>
<i>Padi Tuya</i>	8.55 ± 0.1 <sup>a</sup>	14.95 ± 0.8 <sup>ab</sup>	13.28 ± 0.2 <sup>ab</sup>	7.60 (2.76) ± 0.0 <sup>a</sup>	7.79 (2.79) ± 0.1 <sup>a</sup>	13.89 ± 1.2 <sup>cd</sup>	25.19 ± 1.0 <sup>d</sup>	59.2 ± 0.5 <sup>d</sup>
<i>Wang Kae</i>	12.16 ± 0.3 <sup>c</sup>	24.01 ± 6.4 <sup>c</sup>	15.94 ± 1.1 <sup>bc</sup>	9.60 (3.10) ± 0.0 <sup>bc</sup>	10.96 (3.31) ± 0.1 <sup>b</sup>	15.78 ± 0.9 <sup>d</sup>	27.41 ± 0.0 <sup>e</sup>	64.9 ± 0.3 <sup>e</sup>
p- value	0.094	0.045	0.012	0.004	0.008	0.001	0.001	0.001

Means within columns with the same letter are not significantly different ( $P > 0.05$ ), while different letters indicate significance between values. Values in brackets are log transformed means of the respective mean.



## 4.2 Laboratory experiments

### 4.2.1 Repellency of cowpea extracts against *Callosobruchus maculatus*.

Tables 9 and 10 show the repellency of the selected cowpea extracts against *Callosobruchus maculatus*. All extracts exhibited repellency against *Callosobruchus maculatus* and the mean percentage repellency increased with increased extract concentration.

At 1g/mL of acetone extract, 'Kirkhouse' recorded the highest repellency of 26.7% against *C. maculatus* while 'Wang Kae' recorded no repellency (i.e. 0%). Meanwhile, 'Kirkhouse' recorded the highest repellency of 53.3% against *C. maculatus* while 'Padi Tuya' recorded the least repellency of 6.7% at 1g/mL of methanol extract.

At 2g/mL of acetone extract, 'Golinga' recorded the highest repellency of 73.3% against *C. maculatus* while 'Asontem' and 'Wang Kae' recorded the least repellency of 33.3%. Meanwhile, at 2g/mL of methanol extract, 'Asontem' recorded the highest repellency of 86.7% against *C. maculatus* while 'Golinga' recorded the least repellency of 33.3%.



Table 1: Mean percentage repellency of the two extraction methods (acetone and methanol) on *Callosobruchus maculatus*

Variety	1g/mL Acetone	2g/mL Acetone
	Mean $\pm$ S.E.	Mean $\pm$ S.E.
<i>Asontem</i>	25.0 (29.8) $\pm$ 3.2 <sup>b</sup>	33.3 (35.2) $\pm$ 2.0 <sup>a</sup>
<i>Golinga</i>	16.7 (23.9) $\pm$ 2.7 <sup>b</sup>	73.3 (59.0) $\pm$ 2.2 <sup>c</sup>
<i>Kirkhouse</i>	26.7 (30.8) $\pm$ 2.7 <sup>b</sup>	60.0 (50.8) $\pm$ 0.0 <sup>b,c</sup>
<i>Padi Tuya</i>	23.3 (28.8) $\pm$ 4.2 <sup>b</sup>	46.7 (42.7) $\pm$ 8.1 <sup>a,b</sup>
<i>Wang Kae</i>	0.0 (0.0) $\pm$ 2.2 <sup>a</sup>	33.3 (35.2) $\pm$ 2.0 <sup>a</sup>
p value	0.008	0.005

Means within columns with same letters are not significantly different ( $P > 0.05$ ), while different letters indicate significance between values. Values in brackets are log transformed means of the respective means.

Table 2: Mean percentage repellency of methanol extracts of cowpea varieties on *Callosobruchus maculatus*.

Variety	1g/mL Methanol	2g/mL Methanol
	Mean $\pm$ S.E.	Mean $\pm$ S.E.
<i>Asontem</i>	46.7 (43.1) $\pm$ 1.9 <sup>d</sup>	86.7 (68.9) $\pm$ 2.7 <sup>d</sup>
<i>Golinga</i>	33.3 (35.2) $\pm$ 2.0 <sup>c</sup>	33.3 (35.2) $\pm$ 2.0 <sup>a</sup>
<i>Kirkhouse</i>	53.3 (46.9) $\pm$ 1.9 <sup>d</sup>	66.7 (54.8) $\pm$ 2.0 <sup>c</sup>
<i>Padi Tuya</i>	6.7 (14.9) $\pm$ 1.4 <sup>a</sup>	66.7 (54.8) $\pm$ 2.0 <sup>c</sup>
<i>Wang Kae</i>	13.3 (21.4) $\pm$ 0.6 <sup>b</sup>	53.3 (46.9) $\pm$ 1.9 <sup>b</sup>
p value	0.001	0.001

Means within columns with same letters are not significantly different ( $P > 0.05$ ) while different letters indicate significance between values. Values in brackets are log transformed means of the respective means.

#### 4.2.2 Adult Mortality

All the five cowpea varieties recorded mortality after four days of introducing the *C. maculatus* adults onto the seeds. ‘Asontem’ recorded the highest percentage (43.3%) adult mortality while ‘Wang Kae’ recorded the least percentage (10.0%). Adult mortality increased for all varieties seven days after introducing *C. maculatus*. There were significant differences among the mean percentage mortalities of the cowpea varieties.

Table 3: Mean percentage mortality of *C. maculatus* adults after different incubation days

Variety	After 4 days	After 7 days	After 10 days
<i>Asontem</i>	43.3 (41.2) ± 1.9 <sup>d</sup>	56.7 (48.9) ± 1.9 <sup>d</sup>	56.7 (48.9) ± 1.9 <sup>d</sup>
<i>Golinga</i>	33.3 (35.2) ± 2.0 <sup>c</sup>	46.7 (43.1) ± 1.9 <sup>c</sup>	46.7 (43.1) ± 1.9 <sup>c</sup>
<i>Kirkhouse</i>	26.7 (31.1) ± 1.1 <sup>c</sup>	36.7 (37.3) ± 1.0 <sup>b</sup>	36.7 (37.3) ± 1.0 <sup>b</sup>
<i>Padi Tuya</i>	20.0 (26.6) ± 0.0 <sup>b</sup>	40.0 (39.2) ± 0.0 <sup>b,c</sup>	40.0 (39.2) ± 0.0 <sup>b,c</sup>
<i>Wang Kae</i>	10.0 (18.4) ± 0.0 <sup>a</sup>	26.7 (31.0) ± 2.2 <sup>a</sup>	26.7 (31.0) ± 2.2 <sup>a</sup>
p value	0.001	0.001	0.001

Means within columns with same letters are not significantly different ( $P > 0.05$ ) while different letters indicate significance between values. Values in brackets are log transformed means of the respective means.

#### 4.2.3 Seed damage

All the cowpea varieties recorded damage for the 6-week period after introducing the *Callosobruchus maculatus*. ‘Padi Tuya’ recorded the highest (13%) seed damage whereas ‘Asontem’ recorded the least (7.9%). There were significant differences ( $p < 0.05$ ) among the mean percentage seed damage of ‘Asontem’, ‘Golinga’ and ‘Padi Tuya’ varieties but there was no significant difference between ( $p > 0.005$ ) ‘Kirkhouse’ and ‘Wang Kae’ (Table 12).

#### 4.2.4 Percentage seed weight loss

All the varieties recorded losses in seed weight, with ‘Padi Tuya’ recording the highest mean percentage seed weight loss and ‘Asontem’ recording the least mean percentage seed weight loss

(Table 12). Mean percentage seed weight losses in ‘Golinga’, ‘Kirkhouse’ and ‘Wang Kae’ were not significantly different. Mean percentage seed weight loss in ‘Asontem’ and ‘Padi Tuya’ was significantly different ( $p>0.05$ ) while there were significant differences ( $p<0.05$ ) between the mean percentage seed weight loss recorded for ‘Asontem’ and ‘Padi Tuya’.

#### 4.2.5 Median Development Period (MDP) for *Callosobruchus maculatus*

The MDP ranged from 17 days for ‘Wang Kae’ to 28 days for ‘Asontem’ as shown in Table. 12. The mean median development period was significantly different between ‘Asontem’, ‘Kirkhouse’, ‘Padi Tuya’ and ‘Wang Kae’. ‘Asontem’ recorded the highest median development period of 28.50 day while ‘Wang Kae’ recorded the least median development period of 17 days.

#### 4.2.6 Susceptibility of cowpea varieties to attack by *Callosobruchus maculatus*

The susceptibilities of the five cowpea varieties to attack by *C. maculatus* during the six weeks of storage is shown by the susceptibility indices recorded in Table 12. Using the scale adopted from Dobie (1974), ‘Asontem’, ‘Golinga’, ‘Kirkhouse’ and ‘Wang Kae’ were classified as moderately resistant (S.I.= 6.3, 7.0, 7.2, 6.5) to infestation by *C. maculatus* while Padi Tuya was classified as susceptible (S.I= 8.3).

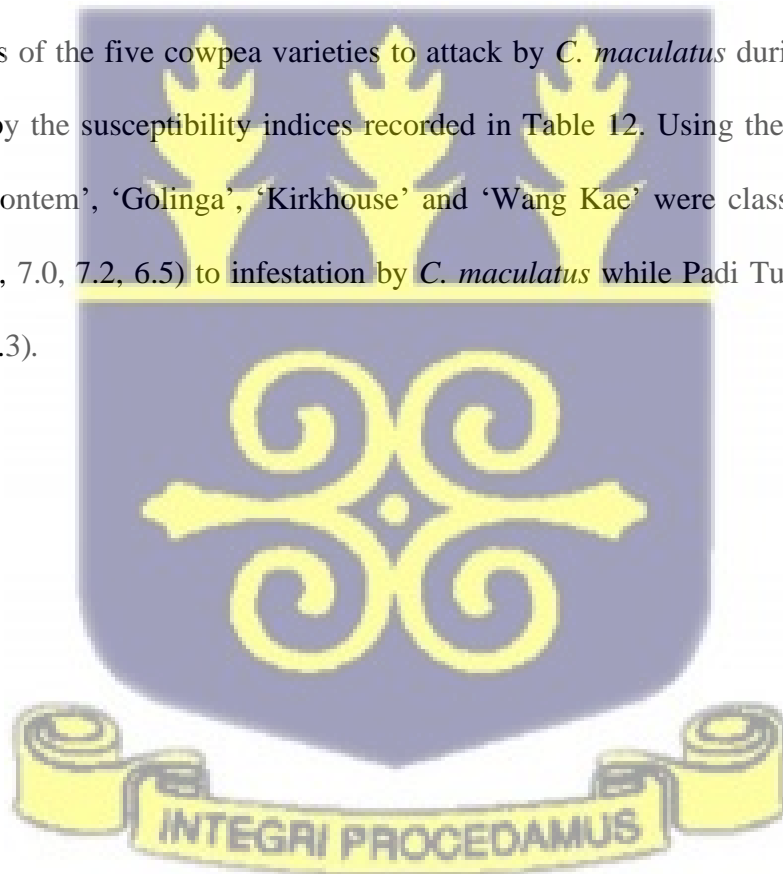


Table 4: Mean percentage Seed Damage, Percentage Weight Loss, Median Development Period (MDP) and Susceptibility Index of cowpea varieties to *Callosobruchus maculatus*

Variety	Percentage Seed Damage	Percentage Seed Weight Loss (g) Mean ± S.E.*	MDP (Days)	Susceptibility Index **
<i>Asontem</i>	7.9 (16.3) ± 0.1 <sup>a</sup>	0.5 (3.9) ± 0.3 <sup>a</sup>	28.50 ± 0.5 <sup>d</sup>	6.3 ± 0.0
<i>Golinga</i>	9.5 (18.0) ± 0.2 <sup>b</sup>	1.3 (6.6) ± 0.3 <sup>b</sup>	27.50 ± 0.5 <sup>cd</sup>	7.0 ± 0.2
<i>Kirk House</i>	11.4 (19.7) ± 0.3 <sup>c</sup>	1.3 (6.6) ± 0.4 <sup>b</sup>	26.00 ± 1.0 <sup>c</sup>	7.2 ± 0.3
<i>Padi Tuya</i>	13.0 (21.1) ± 0.1 <sup>d</sup>	2.5 (9.1) ± 0.5 <sup>c</sup>	23.50 ± 0.5 <sup>b</sup>	7.3 ± 2.3
<i>Wang Kae</i>	11.8 (20.1) ± 0.4 <sup>c</sup>	1.2 (6.3) ± 0.1 <sup>b</sup>	17.50 ± 0.5 <sup>a</sup>	6.5 ± 1.2
p value	0.001	0.002	0.001	0.752

\*Means within columns with same letters are not significantly different ( $P > 0.05$ ), while different letters indicate significance between values. Values in brackets are log transformed means of the respective means.

\*\* The Susceptibility index used to classify the cowpea varieties are 0-3= resistant, 4-7= moderately resistant, 8-10= susceptible and  $\geq 10$ = highly susceptible (Dobie, 1974) from the 5<sup>th</sup> column.

#### 4.2.7 Phytochemical screening of selected cowpea varieties

Qualitative and quantitative phytochemical analyses on the selected cowpea varieties confirmed the presence of different levels of phenols, flavonoids, tannins and alkaloids. The phytochemical analyses showed that the phenols were composed of gallic acid, vanillic acid, and P-coumaric, while flavonoids were composed of rutin and quercetin. As shown in Table 13, 'Asontem' recorded the highest phenolic content of 5.1mg/mL gallic acid, 10.6mg/mL vanillic acid, 18.2mg/mL P-coumaric, and flavonoid content of 2.7mg/mL rutin and 0.4mg/mL quercetin, whereas 'Padi Tuya' recorded the least phenolic content of 1.0mg/mL gallic acid, 3.2mg/mL vanillic acid and 5.3mg/mL P-coumaric and flavonoid content with values being 0.4mg/mL rutin and 0.0mg/mL quercetin.

Table 5: Mean phytochemical levels in cowpea varieties

Variety	Phenols			Flavonoid	
	Gallic Acid	Vanillic Acid	P-Coumaric	Rutin	Quercetin
	Mean mg/mL $\pm$ S.E.			Mean mg/mL $\pm$ S.E.	
<i>Asontem</i>	5.1 $\pm$ 0.0 <sup>c</sup>	10.6 $\pm$ 0.0 <sup>c</sup>	18.2 $\pm$ 0.0 <sup>c</sup>	2.7 $\pm$ 0.0 <sup>d</sup>	0.4 $\pm$ 0.0 <sup>d</sup>
<i>Golinga</i>	3.4 $\pm$ 0.7 <sup>b</sup>	7.7 $\pm$ 1.3 <sup>b</sup>	13.1 $\pm$ 2.2 <sup>b</sup>	1.8 $\pm$ 0.0 <sup>c</sup>	0.2 $\pm$ 0.0 <sup>c</sup>
<i>Kirkhouse</i>	1.4 $\pm$ 0.0 <sup>a</sup>	4.0 $\pm$ 0.0 <sup>a</sup>	6.7 $\pm$ 0.0 <sup>a</sup>	0.7 $\pm$ 0.0 <sup>b</sup>	0.1 $\pm$ 0.0 <sup>b</sup>
<i>Padi Tuya</i>	1.0 $\pm$ 0.0 <sup>a</sup>	3.2 $\pm$ 0.0 <sup>a</sup>	5.3 $\pm$ 0.0 <sup>a</sup>	0.4 $\pm$ 0.0 <sup>a</sup>	0.0 $\pm$ 0.0 <sup>a</sup>
<i>Wang Kae</i>	1.0 $\pm$ 0.0 <sup>a</sup>	3.2 $\pm$ 0.0 <sup>a</sup>	5.4 $\pm$ 0.0 <sup>a</sup>	0.7 $\pm$ 0.0 <sup>b</sup>	0.1 $\pm$ 0.0 <sup>b</sup>
p value	0.001	0.001	0.001	0.001	0.001

Means within columns with same letters are not significantly different ( $P > 0.05$ ) while different letters indicate significance between values. Values in brackets are log transformed means of the respective means.



## 5.0 DISCUSSION

### 5.1 Insect pest infestations on selected cowpea varieties at different developmental stages in the field

Generally, all the five cowpea varieties were susceptible to insect pest infestations in both the major and minor seasons. This was an indication that none of the varieties used was resistant to any of the field pests encountered. Two weeks after germination, it was observed that *Aphis craccivora*, *Zonocerus variegatus* and *Ophiomyia phaseoli* were found feeding on young cowpea plants of the different varieties. Due to no application of insecticides during the period of study, the number of insect pests increased during the major and minor seasons.

During the vegetative growth stage, *Zonocerus variegatus* was observed feeding on the leaves and tender shoots of the different varieties of the young cowpea plants in the minor season. *Aphis craccivora* was observed round the stem, young leaves and young shoot in both major and minor seasons.

Damage caused by *Megalurothrips sjostedti* at the reproductive growth stage impacted negatively on pod formation and the number of pods formed. It was observed that 'Wang Kae' recorded the highest flower thrip infestation but recorded the second highest number of pods, an indication that infestation of all cowpea plants ('Wang Kae') with *M. sjostedti* did not significantly affect pod formation in that variety. This could be attributed to the phenomenon of tolerance which is based on the assumption that infestation and damage are not synonymous (Singh and Jackai, 1985). Thus, 'Wang Kae' which recorded the largest infestation, produced more pods than 'Asontem' and 'Kirkhouse' in the minor season.

### 5.2 Effect of insect pest infestations on yield.

During the vegetative growth stage, the plants were infested with *Aphis craccivora* two weeks after germination. The insect feeding activities deprive the plants of essential nutrients (Baidoo

*et al.*, 2012) and also lead to transmission of viral diseases (Chalfant,1976). *Aphis craccivora* feeds on the stem, terminal shoot and petioles of the seedling causing stunted growth and death of affected plants (Chalfant *et al.*, 1985). Aphids reproduce at a high rate, hence, the rapid increase in their numbers. The total yield of the cowpea varieties negatively correlated with the *A. craccivora* infestation in both seasons, which indicated that the yields of the cowpea varieties reduced with increasing *A. craccivora* infestation.

During the reproductive growth stage, *Megalurothrips sjostedti* was observed attacking the flower buds and flowers in both major and minor seasons. The results of the study indicated that mean number of *Megalurothrips sjostedti* did not differ significantly among the cowpea varieties in both seasons. The nymphs and adults of *M. sjostedti* were observed feeding on the bract and stipules of the plants which led to deformation. These pests also attacked the flower buds and flowers. The negative correlation between the yield of the cowpea varieties and *M. sjostedti* infestation in both seasons indicates that, increasing *M. sjostedti* infestations reduced the yield of cowpea varieties.

During pod maturity stage, the borer, *Maruca vitrata* caused significant damage to ‘Padi Tuya’ in both seasons, leading to significantly lower yield. Generally, *Maruca vitrata* is a major insect pest of cowpea that causes severe damage to the pods, where matured larvae typically fed on the newly formed pods. Similar observations have been reported by Okeyo-Owuor *et al.* (1983).

### **5.3 Effect of *Callosobruchus maculatus* on the seeds of different cowpea varieties in the laboratory**

#### **5.3.1 Median Development Period and Susceptibility Index**

The median development period of *C. maculatus* on all the cowpea varieties ranged between 17 to 28 days, which fall outside the range of susceptible varieties to *C. maculatus* as reported by Beck and Blumer (2007) that the median development period on susceptible varieties ranged

from 21 to 25 days. Hill (1990) had reported earlier a median development period of 22 to 23 days or longer, depending on environmental conditions.

The result of the present study showed that four of the cowpea varieties were moderately resistant to *C. maculatus*. It was expected because Lephale *et al.* (2012) and Amusa *et al.* (2013) reported that improved yield varieties are generally resistant to *C. maculatus* than landrace ones (Keneni, 2011). Lephale *et al.* (2012) further indicated that some characteristics such as seed size, testa thickness, and hardness in the genotypes may influence cowpea seed reaction to *C. maculatus* attack.

### 5.3.2 Seed damage and weight loss

Seed weight losses can largely be attributed to seed damage during the storage period. The study showed that four cowpea varieties ('Asontem', 'Golinga', 'Kirkhouse' and 'Wang Kae') were moderately resistant, while 'Padi Tuya' was susceptible. 'Asontem' suffered the least seed damage and lost the least weight, while 'Padi Tuya' suffered the highest for both. Tadesse (1991) and Tefera *et al.* (2011) reported that the level of seed harm during storage period depends on the number of adults emerging for F<sub>1</sub> progeny, and the period of each life cycle and varieties. Less seed harm can be due to antixenosis mechanisms like smooth pericarp which can discourage *C. maculatus* from laying eggs and growing (Muzemu *et al.*, 2013). It is known that in most of the cases, damage generally has a positive relationship with the number of weevils, which means that as the latter increases, damage also increases. It has also been reported that different maize varieties such as High Protein Maize (ART/98/SW1) and Quality Protein Maize (ART/98/SW6-OB) respond differently to maize weevil infestations (Horber, 1988; Giga *et al.*, 1991; Arnason *et al.*, 1993).

### 5.3.3 Repellency of extracts of cowpea varieties to *Callosobruchus maculatus*

Generally, methanol and acetone extracts of the cowpea varieties were repellent to *Callosobruchus maculatus* at the different concentrations. Most of the insects were found on the untreated filter paper due to the repellent activity of the cowpea extracts. The methanol

extract exhibited higher repellency against *Callosobruchus maculatus* compared to the acetone extract. Owusu *et al.* (2007), Eziah *et al.* (2013) and Buxton *et al.* (2014) reported that methanol extracts of *Zanthoxylum xanthoxyloides* was an effective repellent to stored product beetles.

The performances of the plant species in repelling the insects indicate the presence of chemical compounds that stimulate or cause the insects to avoid or make oriented movement away from the stimulus source (Dethier *et al.*, 1960). The high level of repellency exhibited by some of the plant species implies high amounts of these compounds in the treatments. Awita and Duodu (2016) reported that the major phenolic compounds present in leguminous seeds, particularly in cowpea, are the phenolic acids and flavonoids. Nassourou *et al.* (2016) also reported that flavonoids also play an important role in plant protection.

#### 5.3.4 Phytochemical analysis

The phytochemical screening results revealed the presence of flavonoids, phenols, alkaloids and tannins as secondary metabolites. Their detection was possible because of the reaction of the functional groups with reagents to produce different colours and changes in physical nature (Adesina, 1986; Trease and Evans, 1989).

All the five cowpea varieties recorded some repellency for both methanol and acetone extracts of the cowpeas and repellency increased with increase in concentration of the extracts. The insects that were introduced onto the filter paper immediately moved towards the untreated half of the filter paper for a long while until 24 hours where it was observed that some has settled on the cowpea extract treated half of the filter paper. Secondary plant chemicals are known to attract or repel insects and influence their locomotion, oviposition, feeding behaviour, developmental and physiological process (Obeng-Ofori *et al.*, 1998). It is therefore possible that the insects were repelled from the treated half of the filter paper due to the phytochemicals present in the cowpea extracts.

The significant low seed damage caused by *C. maculatus* as well as high insect mortality could be attributable to the presence of toxic secondary metabolites in the various cowpea extracts. This has also been reported in *Dracaena arborea* where a significant low damage in stored grains and high *Sitophilus zeamais* and *Callosobruchus maculatus* mortality was attributed to the presence of toxic secondary metabolites (Okunji *et al.*, 1996; Momeni *et al.*, 2005).

Eziah *et al.* (2013) reported that methanol extracts of the leaves and roots of *Zanthoxylum xanthoxyloides* and the roots extracts of *Securidaca longepedunculata* were bioactive against *Prostephanus truncatus* and *Tribolium castaneum*. It is known that some secondary metabolites may act both as insecticides and anti-feedants as had been observed for rotenone against the Red flour beetle, *Tribolium castaneum* (Herbst) (Nawrot *et al.*, 1988) and other rotenoids against lepidopteran pests such as the African armyworm, *Spodoptera exempta* (Walker), the African sugarcane borer, *Eldana saccharina* Walker and the legume pod borer, *Maruca vitrata* (Fab.) (Hassanali and Lwande, 1989).



## 6.0 CONCLUSIONS AND RECOMMENDATIONS

### 6.1 Conclusions

Different species of insects are associated with cowpea at different stages of its growth. The study has shown that all the five cowpea varieties encountered insect pest attack at different developmental stages in the field. The pod maturity stage attracted more insect species (10 species) than the vegetative (7 species) and reproductive growth (8 species) stages.

The yield of all the cowpea varieties reduced due to insect pest attack, as no pest control measure was adopted to control the pests in the field. Generally, the yield of cowpea varieties in the major season was higher than the yield in the minor season.

Methanol and acetone extracts of the cowpea varieties were effective in controlling adult *Callosobruchus maculatus*, in repelling the insects. All cowpea varieties were resistant to attack by *C. maculatus* in the laboratory, except 'Padi Tuya'.

Phytochemicals, such as, flavonoids and phenols, tannins and alkaloids were detected in the cowpea varieties, and this possibly caused repellence or low seed damage by *C. maculatus*.

### 6.2 Recommendations

The following are recommended based on the findings of the study:

- If the goal of increasing cowpea yield is to be realized, improved varieties must be planted, as well as pest management strategies adopted both in the field and during storage, as no pest control measures were adopted in this study.
- Further study is needed to ascertain the effect of the cowpeas extracts on other storage insect pests.
- Further studies are needed to find out the specific phytochemical constituent or constituents of the cowpea seeds that causes toxicity and repellency.

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APPENDICES

**APPENDIX 1: Analysis of variance for mean number of insect pests recorded at the vegetative growth stage**

**Analysis of variance for *Zonocerus variegatus* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.3280	0.1093	0.89	
Rep.*Units* stratum					
Treatment	4	0.4901	0.1225	1.00	0.444
Residual	12	1.4666	0.1222		
Total	19	2.2847			

**Analysis of variance for *Ophiomyia phaseoli* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.33629	0.44543	4.64	
Rep.*Units* stratum					
Treatment	4	1.06489	0.26622	2.77	0.077
Residual	12	1.15241	0.09603		
Total	19	3.55359			

**Analysis of variance for *Aphis craccivora* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.42560	0.14187	3.36	
Rep.*Units* stratum					
Treatment	4	1.09776	0.27444	6.50	0.005
Residual	12	0.50633	0.04219		
Total	19	2.02969			

**Analysis of variance for *Aphis craccivora* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	17.004	4.251	0.71	0.597
Residual	15	89.638	5.976		
Total	19	106.642			

**Analysis of variance for *Empoasca sp.* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.05013	0.01671	0.36	
Rep.*Units* stratum					
Treatment	4	5.88688	1.47172	31.78	<.001
Residual	12	0.55577	0.04631		
Total	19	6.49278			

**Analysis of variance for *Oothea mutabilis* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.000	0.333	0.24	
Rep.*Units* stratum					
Treatment	4	36.200	9.050	6.39	0.005
Residual	12	17.000	1.417		
Total	19	54.200			

**Analysis of variance for *Camponotus pennsylvanicus* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	16.473	4.118	2.28	0.109
Residual	15	27.126	1.808		

Total 19 43.599

**Analysis of variance for *Coccinellidae* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	0.034315	0.008579	1.00	0.438
Residual	15	0.128680	0.008579		
Total	19	0.162994			

**Analysis of variance for *Podagrica uniformis* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Treatment	4	0.12010	0.03003	1.05	0.415
Residual	15	0.42893	0.02860		
Total	19	0.54903			



**APPENDIX 2: Analysis of variance for mean number of insect pests recorded at the reproductive growth stage**

**Analysis of variance for *Zonocerus variegatus* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.12473	0.04158	0.73	
Rep.*Units* stratum					
Treatment	4	1.00829	0.25207	4.42	0.020
Residual	12	0.68373	0.05698		
Total	19	1.81676			

**Analysis of variance for *Zonocerus variegatus* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.41448	0.13816	2.55	
Rep.*Units* stratum					
Treatment	4	0.83774	0.20944	3.87	0.030
Residual	12	0.64905	0.05409		
Total	19	1.90127			

**Analysis of variance for *Ophiomyia phaseoli* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.39735	0.13245	6.61	
Rep.*Units* stratum					
Treatment	4	1.15142	0.28786	14.37	<.001
Residual	12	0.24030	0.02002		
Total	19	1.78907			

**Analysis of variance for *Megalurothrips sjostedti* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.3149	0.4383	0.74	
Rep.*Units* stratum					
Treatment	4	6.9793	1.7448	2.96	0.065
Residual	12	7.0655	0.5888		
Total	19	15.3597			

**Analysis of variance for *Megalurothrips sjostedti* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	3.215	1.072	1.07	
Rep.*Units* stratum					
Treatment	4	7.589	1.897	1.89	0.176
Residual	12	12.029	1.002		
Total	19	22.833			

**Analysis of variance for *Mylabris sp.* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.4273	0.4758	1.05	
Rep.*Units* stratum					
Treatment	4	4.5578	1.1395	2.52	0.097
Residual	12	5.4325	0.4527		
Total	19	11.4176			

**Analysis of variance for *Cydia ptychora* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.7072	0.2357	1.83	
Rep.*Units* stratum					
Treatment	4	1.1791	0.2948	2.28	0.120
Residual	12	1.5488	0.1291		
Total	19	3.4351			

Total 19 1.36654

**Analysis of variance for *Aphis craccivora* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.07580	0.02527	1.00	
Rep.*Units* stratum					
Treatment	4	0.26278	0.06570	2.60	0.089
Residual	12	0.30319	0.02527		
Total	19	0.64178			



**APPENDIX 3: Analysis of variance for mean number of insect pests recorded at the pod maturity stage**

**Analysis of variance for *Maruca vitrata* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.83878	0.27959	13.14	
Rep.*Units* stratum					
Treatment	4	2.27991	0.56998	26.78	<.001
Residual	12	0.25540	0.02128		
Total	19	3.37409			

**Analysis of variance for *Maruca vitrata* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.3950	0.4650	3.24	
Rep.*Units* stratum					
Treatment	4	1.4336	0.3584	2.50	0.098
Residual	12	1.7227	0.1436		
Total	19	4.5513			

**Analysis of variance for *Nezara viridula* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.32901	0.10967	1.83	
Rep.*Units* stratum					
Treatment	4	0.78644	0.19661	3.28	0.049
Residual	12	0.71894	0.05991		
Total	19	1.83440			

**Analysis of variance for *Nezara viridula* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.16040	0.05347	0.99	

Rep.*Units* stratum					
Treatment	4	0.19297	0.04824	0.89	0.497
Residual	12	0.64753	0.05396		
Total	19	1.00089			

**Analysis of variance for *Lampides boeticus* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.6873	0.2291	0.75	
Rep.*Units* stratum					
Treatment	4	3.8117	0.9529	3.12	0.057
Residual	12	3.6705	0.3059		
Total	19	8.1695			

**Analysis of variance for *Lampides boeticus* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.025736	0.008579	1.00	
Rep.*Units* stratum					
Treatment	4	0.034315	0.008579	1.00	0.445
Residual	12	0.102944	0.008579		
Total	19	0.162994			

**Analysis of variance for *Riptortus dentipes* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.5437	0.5146	3.68	
Rep.*Units* stratum					
Treatment	4	1.7644	0.4411	3.16	0.055
Residual	12	1.6773	0.1398		
Total	19	4.9855			

**Analysis of variance for *Riptortus dentipes* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
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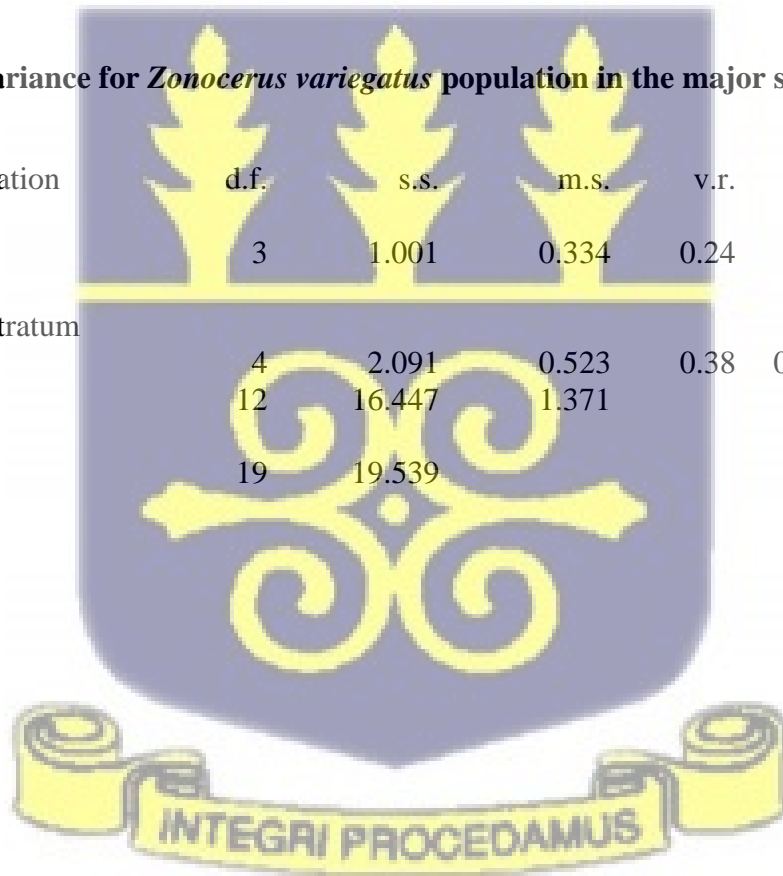
Rep stratum	3	0.6138	0.2046	1.85	
Rep.*Units* stratum					
Treatment	4	0.7534	0.1884	1.71	0.213
Residual	12	1.3248	0.1104		
Total	19	2.6920			

**Analysis of variance for *Zonocerus variegatus* population in the minor season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	0.936	0.312	0.28	
Rep.*Units* stratum					
Treatment	4	2.125	0.531	0.48	0.752
Residual	12	13.339	1.112		
Total	19	16.399			

**Analysis of variance for *Zonocerus variegatus* population in the major season**

Source of variation	d.f.	s.s.	m.s.	v.r.	F pr.
Rep stratum	3	1.001	0.334	0.24	
Rep.*Units* stratum					
Treatment	4	2.091	0.523	0.38	0.818
Residual	12	16.447	1.371		
Total	19	19.539			



APPENDIX 4: Plant Growth Parameters

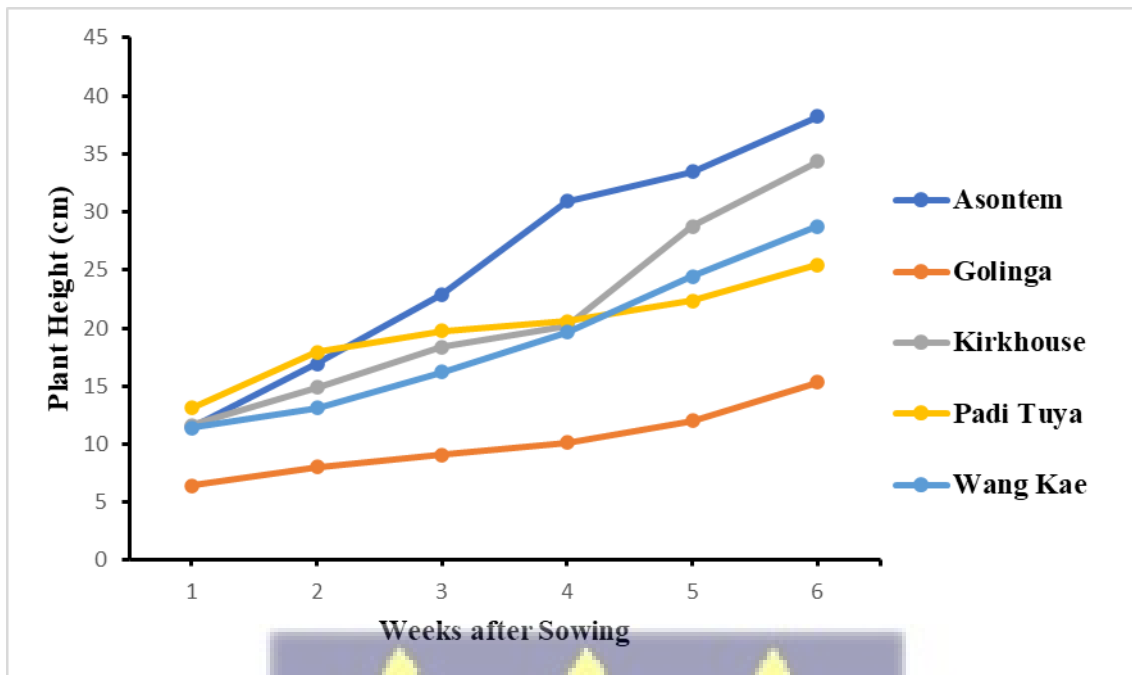


Fig 5: Mean plant height of the cowpea varieties in the minor season.

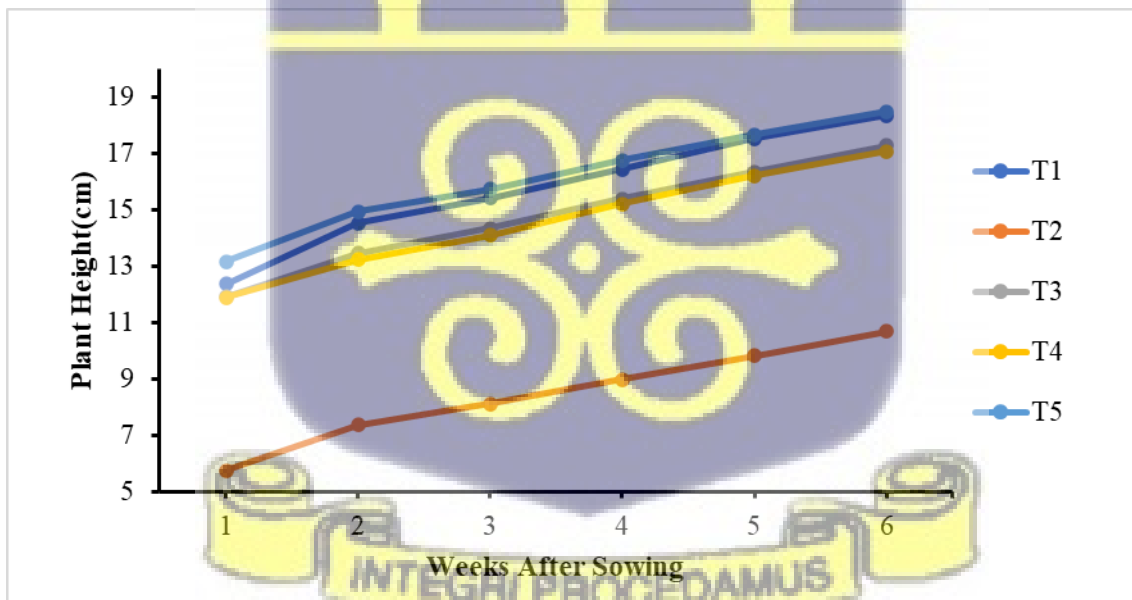


Fig 6: Mean plant height of the cowpea varieties in the major season.

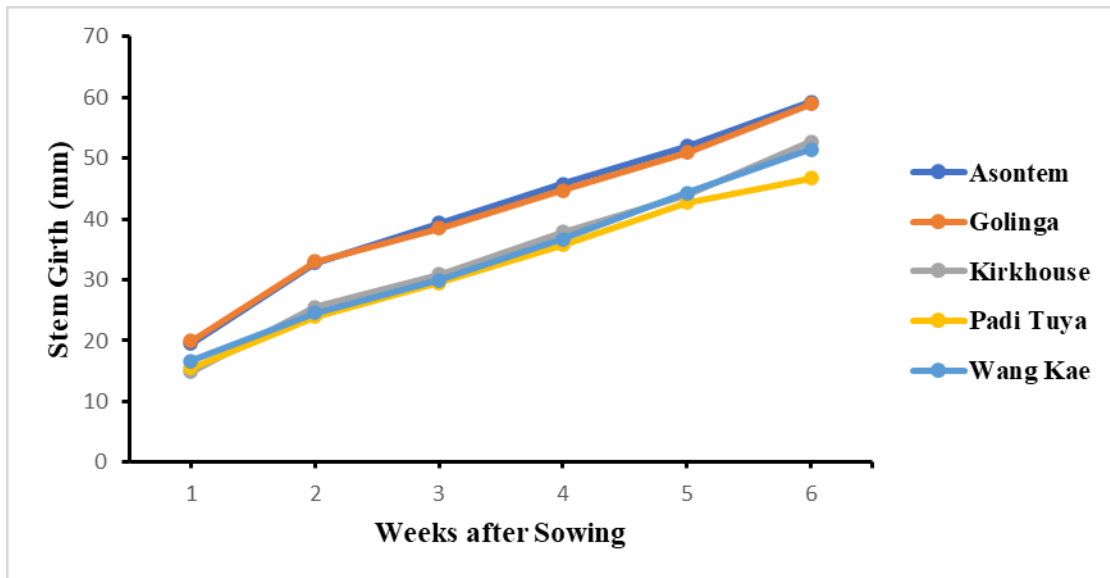


Fig 7: Mean stem girth of the cowpea varieties in the minor season.

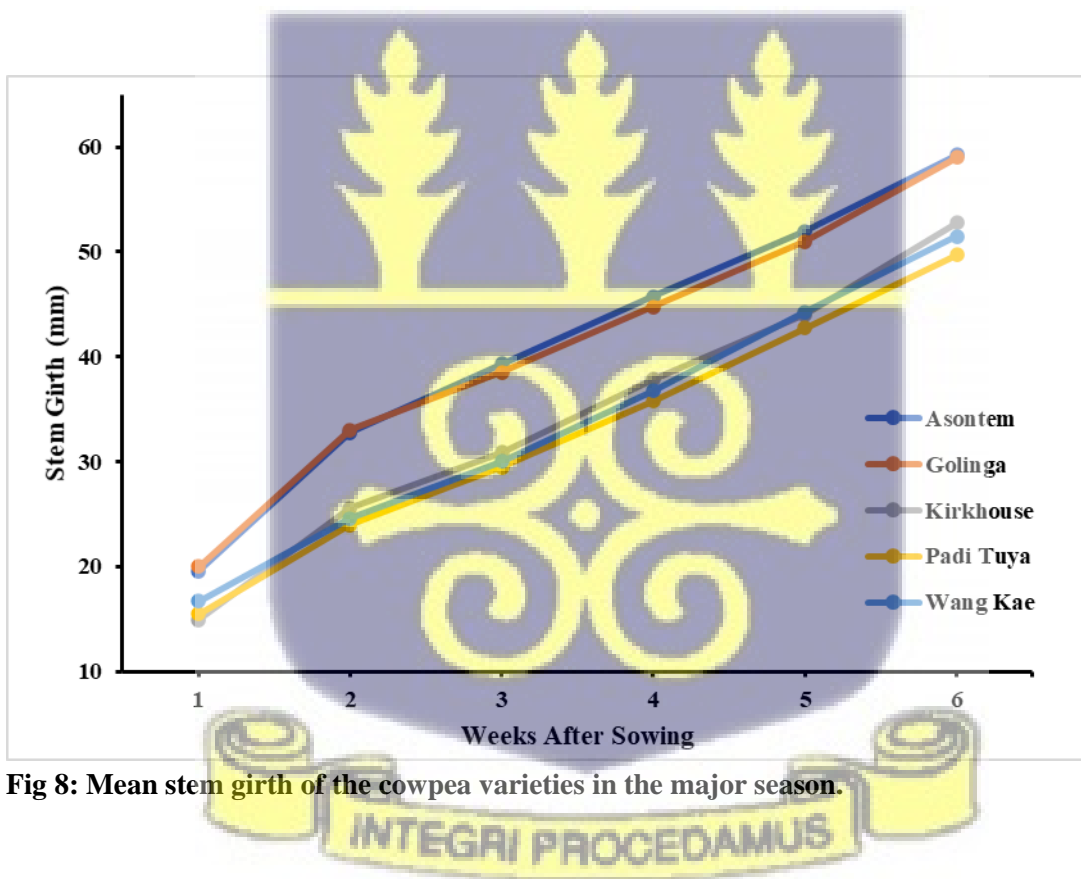


Fig 8: Mean stem girth of the cowpea varieties in the major season.

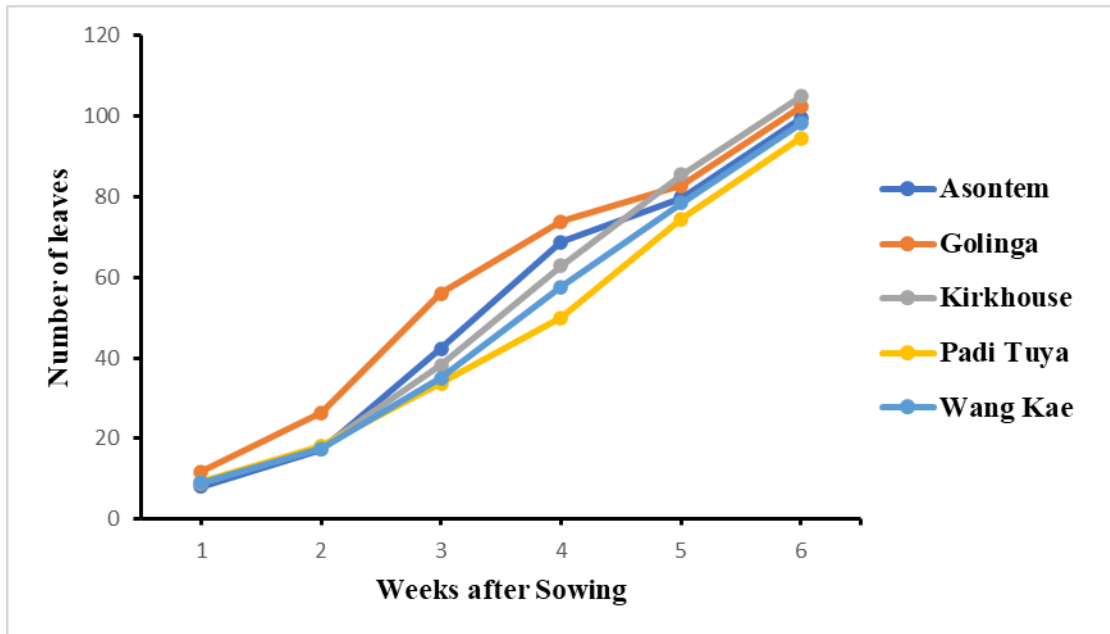


Fig 9: Mean number of leaves of the cowpea varieties in the minor season.

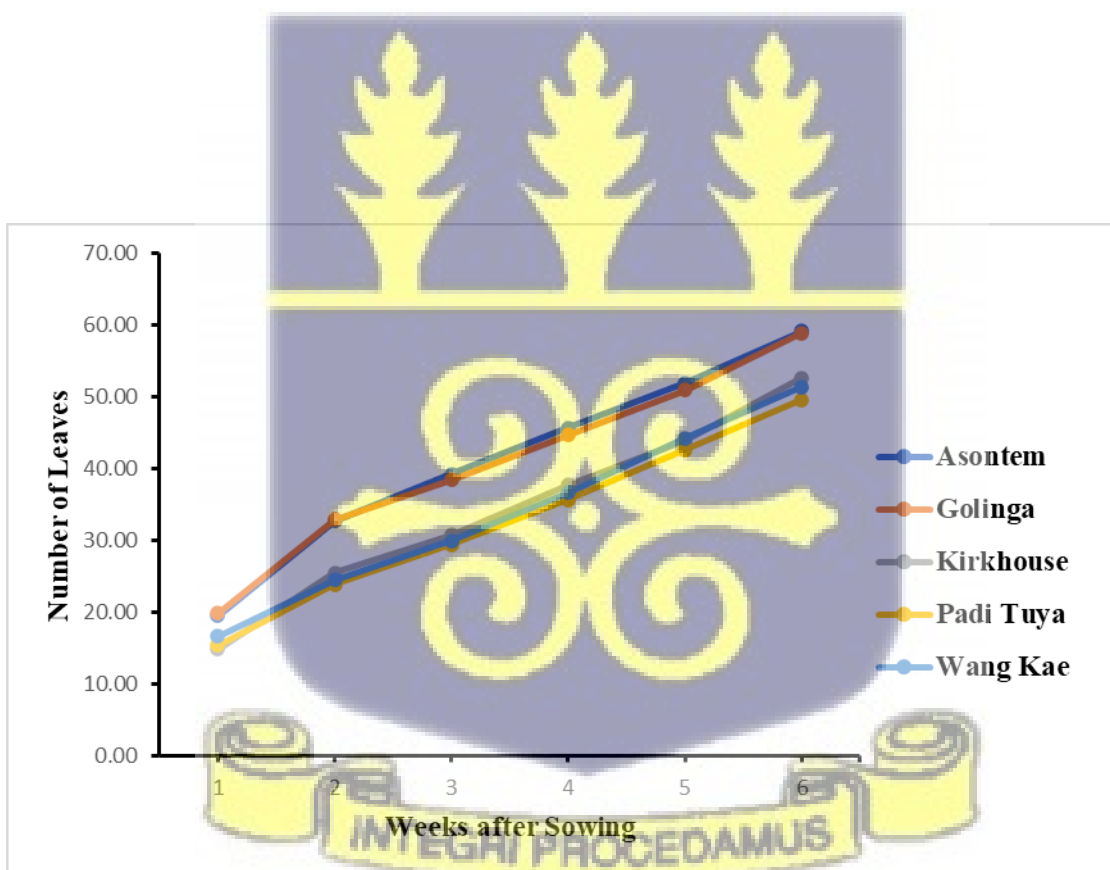


Fig 10: Mean number of leaves of the cowpea varieties in the major.

**APPENDIX 5: Correlation between yield of the cowpea varieties and insect pest infestations in the major season**

***Aphis craccivora***

Yield (g)	1	-	
<i>Aphis. craccivora</i>	2	-0.2368	-
		1	2

Number of observations: 15

Two-sided test of correlations different from zero

Yield (g)	1	-	
<i>A. craccivora</i>	2	0.3954	-
		1	2

***Megalurothrips sjostedti***

Yield (g)	1	-	
<i>M. sjostedti</i>	2	-0.0784	-
		1	2

Number of observations: 15

Two-sided test of correlations different from zero

Yield (g)	1	-	
<i>M. sjostedti</i>	2	0.7812	-
		1	2

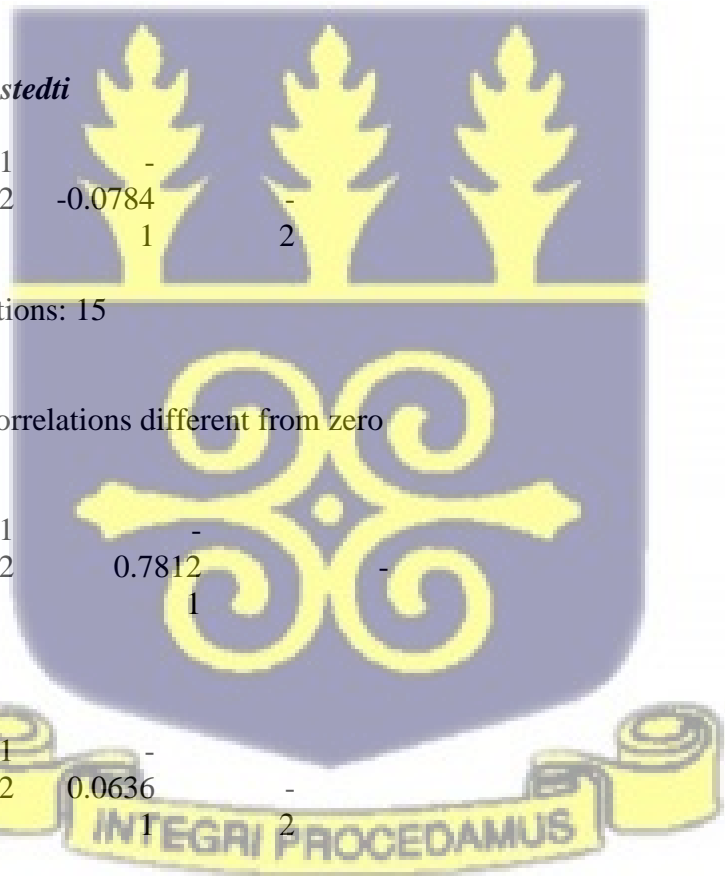
***Maruca vitrata***

Yield (g)	1	-	
<i>M. vitrata</i>	2	0.0636	-
		1	2

Number of observations: 15

Two-sided test of correlations different from zero

Yield (g)	1	-
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<i>M. vitrata</i>	2	0.8220	-
		1	2



**APPENDIX 6: Correlation between yield of the cowpea varieties and insect pest infestations in the minor season**

***Megalurothrips sjostedti***

Yield (g)	1	-	
<i>M. sjostedti</i>	2	-0.4232	-
		1	2

Number of observations: 15

Two-sided test of correlations different from zero

Yield (g)	1	-	
<i>M. sjostedti</i>	2	0.1160	-
		1	2

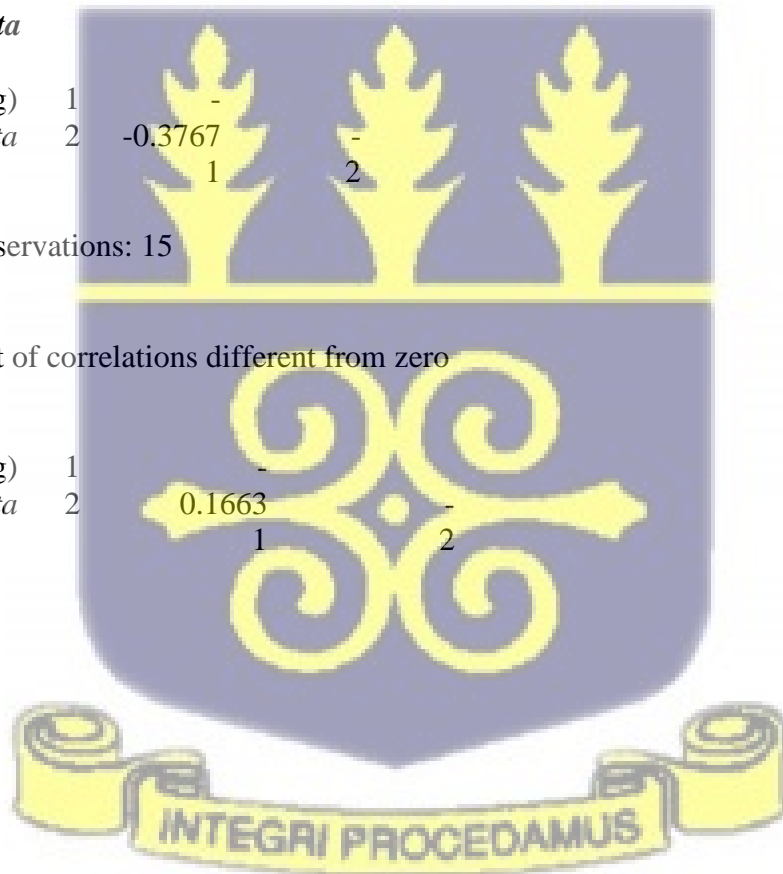
***Maruca vitrata***

Yield (g)	1	-	
<i>M. vitrata</i>	2	-0.3767	-
		1	2

Number of observations: 15

Two-sided test of correlations different from zero

Yield (g)	1	-	
<i>M. vitrata</i>	2	0.1663	-
		1	2



APPENDIX 7: Some pests encountered in the field



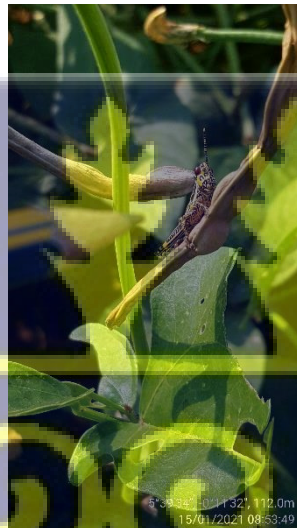
*Aphis craccivora*



*Ophiomyia phaseoli*



*Riptortus dentipes*



*Zonocerus variegatus*



*Mylabris variabilis*



*Lampides boeticus*



*Nezara viridula*