KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY

COLLEGE OF SCIENCE

DEPARTMENT OF THEORETICAL AND APPLIED BIOLOGY

THE EFFECT OF DIFFERENT DOSES OF LAMBDA -CYHALOTHRIN ON *APHIS CRACCIVORA* KOCH (HOMOPTERA: APHIDIDAE) INFESTATION LEVELS AND YIELD OF THREE COWPEA CULTIVARS (*TONA*, *NHYIRA* AND *ASETENAPA*) IN THE FOREST-GUINEA SAVANNAH TRANSITIONAL ZONE (WENCHI MUNICIPALITY), GHANA

BY

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BSc. Natural Resources Management (Hons.)

APRIL, 2013

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BY

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A thesis presented to the Department of Theoretical and Applied Biology, College of Science in partial fulfillment of the requirement for the award of MASTER OF SCIENCE (ENVIRONMENTAL SCIENCE)

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DEDICATION

This dissertation is dedicated to my mother (Saabome Kuubome), sister (Mariama Sule), wife (Helina Saabome) and children (Samuel, Catherine and Evelyn).

DECLARATION

I hereby declare that, this thesis is the result of my own original research carried out under supervision with the exception of people's work, which I have duly referenced. No copy of this thesis has been presented in this university or elsewhere for the award of a degree.

SAABOME ERIC KANGDEM .... 2ND MAY, 2013.

Student Signature Date

Certified by

DR. J. I. ADAM .... 2ND MAY, 2013

Supervisor Signature Date

Certified by

Rev. Stephen Akyeampong .... 2nd May, 2013

Head of Department Signature Date

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ABSTRACT

Cowpea *(Vigna unguiculata)* is one of the important grain legumes widely cultivated in semi arid areas of the tropics and subtropics for human as well as animal consumption. An important threat to the sustained production of the crop is the seedling pest, *Aphis craccivora*.The study was undertaken to verify the minimum dose of the standard chemical insecticide Lambda-cyhalothrin (karate), against three improved cowpea varieties namely *Tona*, *Nhyira* and *Asetenapa*.The experimental design used was Randomized Complete Block Design (RCBD) and there were four treatments of four different doses (0.2 ml, 0.4 ml, 0.6 ml and 0.8 ml) with three replications. Data were collected on the number of plants infested with *A. craccivora*, number of pods per plant, pod weight per plant and seed weight per plant. The effects of the different doses of the insecticide on the level of infestation of *Aphis craccivora* as well as their influence on the yield of the three local cowpea cultivars (*Tona*, *Nhyira* and *Asetenapa*) were also studied. The project was carried out at Wenchi Farm Institute in the Brong-Ahafo Region of Ghana during the minor cropping season (September to December) of 2008. Treatment one (0.2 ml) was the minimum effective dose followed by treatment two (0.4ml), three (0.6 ml) with treatment four (0.8 ml) being the most efficacious dosage of lambda-cyhalothrin for the control of *Aphis craccivora* on the three varieties. Though there were differences between the various treatments, these differences were not statistically significant. *Asetenapa* (0.89 t/ha) was the highest yielding variety followed by *Tona* (0.69 t/ha) with Nhyira (0.63) t/ha) being the lowest yielding variety for treatment four (for the most efficacious 0.8 ml treatment)

CHAPTER ONE

INTRODUCTION

1.1 BACKGROUND

Cowpea (*Vigna unguiculata (L.)* Walp) is a main food crop in tropical Africa (Padulosi and Ng, 1997). It is mainly used as a grain crop or as a vegetable for human consumption as well as for animal fodder (Ehlers and Hall, 1997). It is eaten as either immature or fully ripe. In fresh form, the young leaves and immature pods are used as vegetables, while the grain is used in the preparation of several dishes (Phillips *et al.*, 2003; Etsey *et al.*, 2007).

The Family Leguminosae of which cowpea belongs, is known to contain 500 genera and 12,000 species of herbs, shrubs and trees distributed in most parts of the world (Edwardson and Christie, 1991). Cowpea is indigenous to Africa (Langyintuo *et al.,* 2003) but it has spread worldwide and is extensively cultivated and consumed in Asia, South and Central America, the Caribbean, South Europe. It is also grown in Latin America and Southern United States (Singh, 1985). Globally, Sub-Saharan Africa is the largest producer of cowpea and is responsible for about 70% of the total world production, 7.56 million tonnes grown on 12.76 million hectares (IITA, 2006). According to the Cowpea Production Guide (1990), cowpea is the most widely cultivated legume in Ghana.

The grain is a cheap source of carbohydrate and protein in the diets of humans and livestock in Africa. It is an important source of protein in many parts of the world (Phillips and McWatters, 1991) and is particularly vital in the tropics as it provides the cheapest source of dietary protein and energy leading to it being tagged the "poor man's protein" (Kareem and Taiwo, 2007). It contains 23-38% protein, 60-66% carbohydrates, 5 - 6% fibre and 1–10% of oil (Bressani, 1985). Apart from being a major source of protein, it is a good source of fodder for cattle as well as a rotational and cover crop.

Cowpea is agriculturally significant due to its ability to improve the nutrient quality of poor soils by fixing atmospheric nitrogen (Ennin *et al.*, 2004, Ampomah *et al.*, 2008). The nitrogen fixing capabilities make it an environmentally safe and inexpensive recourse to the application of chemical fertilizers. Generally, it may leave 30 – 125 kg nitrogen per hectare after the harvest of the crop (Ennin-Kwabiah and Osei-Bonsu, 1993). In addition cowpea is cultivated as a green manure crop. Cowpea is also highly drought resistant and can thrive in the semi-arid areas of Africa where there is about 250-750 mm of rainfall with eight months of dry weather (Abate *et al.*, 2000).

1.2 PROBLEM STATEMENT

Insect pests are important constraint to cowpea (*Vigna unguiculata* Walp.) production in the tropics. Ghana has its own share of insect pests with the Ghana/CIDA Grains Development Project reporting in 1991 that insect pests constitute the single most important obstacle to cowpea production in Ghana.

Cowpea is attacked by insects both in the field and storage (Monti *et al.*, 1997). Field pests are a major constraint to cowpea production globally and they attack the grain virtually at every stage of its life-cycle: aphids (*Aphis craccivora*) at the seedling stage, flower thrips (*Megalurothripssjostedti*) at flowering and pod formation as well as by a complex of pod sucking bugs (*Clavigrallatomentosicollis, Anoplocnemiscurvipes* and *Riptortusdentipes*) at podding (Fatokun *et al.*, 2002).

According to Singh and Jackai (1985) the main phytophagous taxa that attack the crop from seedling to harvest can cause economic loss at all stages of plant growth. Losses of cowpea due to insect infestation can be as high as 95%, depending upon the location, year and variety (Gudrups and Bruce (1997). In Africa, insect pests are responsible for 100% losses of cowpea yields and if not controlled, virtually always limit yields to less than 300kg/ha Singh and Jackai(1985). There have been dramatic increases in yields sometimes up to tenfold, have been obtained with the application of insecticides (Singh and Jackai, 1985). These losses are due to the non-availability of resistant cowpea varieties to insect pests and diseases (Ogbuinya, 1997).

Aphis craccivora is the first major pest to attack cowpea during its vegetative stage and is considered one of the most important pests of cowpea and other legumes in Africa, Asia and Latin America (Jackai and Daoust, 1986). In Ghana, *A. craccivora* is a major pest of *Vigna* spp. (Dakora *et al.,* 2004). Aphid infestations cause an alteration in plant source - sink relationships (Girousse *et al.*, 2005), induction of premature leaf senescence (Pegadaraju *et al.*, 2005), reduction in crop yield either through directly sucking plant sap and thus leading to tissue deformities such as leaf curls or galls, early leaf falls, growth slowing (Capinera, 2008) or indirectly by serving as vectors for viral diseases such as the cowpea aphid borne mosaic potyvirus (CABMV) (Bashir *et al.,* 2002). Even though data on the levels of direct damage caused by *A. craccivora* in Ghana is not readily available, the fact that a related species *A. fabae* which also attacks cowpea causes loss of yield of 37% - 90% in Kenya, Zambia, Uganda, Burundi and Tanzania is disturbing indeed (Abate *et al.,* 2000).

Chemical insecticide usage is a "necessary evil" so far as the production of economic quantities of *Vigna unguiculata* is concerned. This state of affairs will exist because until better alternatives are found, chemical insecticdes provide the quickest and surest way of protecting crop plants from insect attacks and ensuring economic returns; the 15-fold and 50–200% yield increases in cultivated cowpea observed in Nigeria and Kenya respectively (Karungi *et al.*, 2000b) back this assertion.

Paradoxically, some of the negative effects attributable to insecticides usage such as bioaccumulation of toxic components, development of insecticide resistance, effects on natural enemies of pests (Tewary *et al.*, 2005) and resurgence outbreaks of some pests (Ofuya, 1997) are rather common in Africa and occur due to inappropriate and unsafe insecticide usage practices such as incorrect dosage application and discretionary spraying regimes without considering pest threshold levels (Ajeigbe and Singh, 2006).

1.3 JUSTIFICATION

The management of insect pests of cowpea is crucial to optimizing production. In an effort to increase yield, some cowpea growers in Ghana particularly those in the BrongAhafo Region in Wenchi and Kintampo are turning to the use of field insecticides. Many field insecticides used on cowpea are foliar sprays, either as emulsifiable concentrates (E.C) or wettable powders (W.P). Several of these chemicals are effective against cowpea pests, although there is greater specificity in some cases against specific groups, or distribution related to the feeding behaviour of different pests. Synthetic pyrethroids are among the commonly used insecticide for controlling agricultural and indoor pests (Liu *et al.*, 2005). The insecticides commonly used include lambda-cyhalothrin (Karate), endosulfan, cypermethrin, permethrin and dimethoate (Jackai and Adalla, 1997).

Lambda-cyhalothrin (known by various names including one local name – Karate) is a pyrethroid widely used for aphid population control in Ghana. The pyrethroids are made from pyrethrum which refers to the oleoresin extracted from the dried flowers of the pyrethrum daisy, *Tanacetumcinerariaefolium* (Asteraceae) with technical grade pyrethrum containing 20 to 25% pyrethrin. Modern synthetic pyrethroids (which bear little resemblance to the natural pyrethrum) have carved a niche for themselves as the predominant insecticide in use globally (Isman, 2006) due largely to their improved photo-stability and rapid knockdown effect on insects.

In the absence of any thresholds (be they Economic or Action Thresholds) for guiding the application of insecticides in Ghana, the norm is for farmers to utilize the insecticide producers recommended dosage or to fall on other alternative sources of advice such as that provided by the IITA Pesticide Guide (Dugje *et al.*, 2008).

From a purely technical standpoint, synthetic insecticides recommended for use on cowpea (e.g. pyrethroids) can effectively control these key pests thereby increasing yields (Singh *et al.*, 1990). The use of these insecticides is associated with environmental and health concerns

(Jackai and Adalla, 1997), as well as socio-economic implications that make the use of chemical insecticides problematic. Among these are low level of farmer education, lack of capital, high prices of pesticides, lack of market and access to recommended insecticide (Jackai and Adalla, 1997). The study was undertaken to determine the minimum insecticide effective dosage for maximum productivity of three locally improved cowpea cultivars (Tona, Nhyira and Asetenapa).

1.4 MAIN OBJECTIVE

The main objective of the study was to determine the minimum dose of Lamda- cyhalothrin on *Aphis craccivora* and yield of three locally improved cowpea cultivars namely Tona, Nhyira and Asetenapa in Forest-Guinea Savanna transitional zone.

1.4.1 SPECIFIC OBJECTIVES

The specific objectives were to determine the:

1. minimum effective dose of lambda-cyhalothrin on Aphids
2. impact of lambda-cyhalothrin on the yield of the cowpea cultivars and
3. impact of Aphids on the yield of the cowpea cultivars

CHAPTER TWO

LITERATURE REVIEW

2.1 CLASSIFICATION AND IDENTIFICATION OF APHIDS

Aphids belong to the Series Sternorrhyncha within the Order Hemiptera, Suborder Homoptera, along with scale insects, psyllids, and whiteflies. They are tiny pear-shaped soft-bodied insects averaging 1mm to 10 mm in length. There are over 4,000 species of aphids with diverse colourations depending on the species as observed in *Myzuspersicae* (the green peach aphid) and *Toxopteracitricada* (the brown citrus aphid). Aphid life cycle displays incomplete metamorphosis with a developmental sequence of egg to nymph and to adult (Capinera, 2008). There are usually four nymphal stages with moulting occurring between each nymphal instar, the nymphs are usually identical miniaturized carbon copies of the adults (they are destined to become) except in some cases where there are different colourations. In *A.craccivora* the nymphs are green and the mature adults black. Another feature is the possession of a distinct cauda (Blackman and Eastop, 2000). Equipped with a piercing and sucking mouthparts called proboscis, aphids are notorious for their sap sucking and virus transmission capabilities (Ofuya, 1997) which are most damaging to the cowpea crop during the seedling stage (Fatokun *et al.*, 2002).The name Sternorrhyncha refers to the position of the rostrum which has its bases between the fore-coxae and in its resting position is deflected back along the ventral surface of the body (Capinera, 2008).

Two aphid species (Homoptera: Aphididae) are reported as pests of cowpea in Africa; *Aphis craccivora* Koch and *Aphis fabae* scopoli (Jackai and Daoust, 1986; Abate *et al.*, 2000).

2.2 LIFE CYCLE OF APHIDS

Aphids are very adaptable insects whose life cycles differ markedly depending on the climate (Pradhan, 1992) with aphids present in the temperate regions of the world being holocyclic (female cyclical parthenogenesis with alternating sexual reproduction between males and females) or anholocyclic (parthenogenic females only) in the tropics and subtropics (Capinera, 2008). Wing polymorphism occurs in aphids with wingless (apterous) forms being the norm during periods of food abundance and stable climate whiles winged forms (alatae or alates) are produced whenever overcrowding occurs and food is in short supply, as well as during adverse climatic conditions (Tokunaga and Suzuki, 2008; Ofuya, 1997).

2.3 APHID POPULATION DYNAMICS

The study of variations in population of aphids is a very daunting task indeed as their high reproductive rates and colonizing habits lead to high density, making enumeration difficult (Verghese and Jayanthi, 2002). As such population dynamics data is invaluable in more ways than one (for instance if one is to come up with Integrated Pest Management policies) and literature is replete with various methods of estimating aphid populations: actual counting (Ofuya and Okuku, 1994), point counting of number of infested plants (Stiling, 1985), direct counting and the creation of a visual rating scale (Karungi *et al.,* 2000a), classification of infestation levels into grades and the application of a formula (Verghese and Jayanthi, 2002).

There is a dearth in long-term studies on population dynamics of aphids living on herbaceous plants (i.e. pest aphids) due to the fact that at any particular time a particular field crop would only support a very small fraction of the shifting aphid population in a region. Mathematical models created using non-pest aphids on largely woody plants have also not been particularly helpful due to the extremely wide oscillations in aphid numbers caused by intrinsic (size, fecundity, mortality, migration rate) and external (weather, especially temperature) factors (Van Emden and Harrington, 2007).

2.4 APHID NUTRITION

Aphids in general and Aphis *craccivora* in particular target host plants capable of supplying them with a steady source of small organic compounds (sugars and amino acids) largely via their phloem (Van Emden and Harrington, 2007). As those host plant sources are usually low in amino acids (the Nitrogen component is what the aphid really needs) they need to imbibe a lot of it and this accounts for their stylet-mediated prodigious feeding habits. The excess sugars are stored temporarily in a dilated rectum and ejected anally forming what is known as honeydew (Capinera, 2008), a substance very useful to symbiotic ants of aphid species (Tokunaga and Suzuki, 2008).

The acquisition of sugars and amino acids occurs passively after stylet insertion due to the higher pressure within the phloem elements and is the reason aphids are termed "phloem feeders". Another sort of feeding which involves active uptake of water from the xylem vessels has been classified "drinking" and is not thought to be of economic significance as it does not seem to contribute to nutrition as such but is a compensatory mechanism from starved water stressed aphids (Van Emden and Harrington, 2007).

2.5 COWPEA VIRUSES - GENERAL BACKGROUND

Out of the more than 700 plant viruses known, sap-feeding insects of the Auchenorrhyncha and the Sternorrhyncha are particularly important vectors and transmit more than 380 of them (Van Emden and Harrington, 2007). The detrimental effects caused by viral diseases are one of the major constraints to the production of the cowpea crop in Africa as the crop is susceptible to more than 20 viral diseases (Singh *et al.*,1997)

In Africa, viral infection estimated losses in Nigeria vary between 10 and 45% depending on the virus-host vector relationship as well as prevailing epidemiological factors (Shoyinka, 1974; Raheja and Leleji, 1974) whiles yield losses of 10 to 100% have been recorded in Uganda (Shoyinka *et al.,* 1997). Interestingly, even though it is a generally well known fact in agricultural circles that viral infestations are common-place, no literature was found quantifying viral effects on cowpea yield in Ghana, a testament to the paucity of information available on Ghana.

According to Hampton *et al.*, (1997) the most insidious and damaging viruses occurring in cowpea around the world (the seed borne viruses) are Blackeye Cowpea Mosaic Potyvirus (BICMV), Cowpea Aphid-Borne Mosaic Potyvirus (CABMV), Cucumber Mosaic Cucumovirus (CMV), Cowpea Severe Mosaic Carmovirus (CPSMV). The viral diseases most prominent in some parts of Africa are: CABMV, Bean Southern Mosaic Virus (SBMV) Cowpea Mottle Virus (CMeV) and Cowpea Yellow Mosaic Virus (CPMV) in Nigeria (Taiwo *et al.*, 2007; Kareem and Taiwo, 2007)); with Aphid Borne Mosaic Virus Disease (ABMVD), Golden Mosaic Virus Disease (GMVD) and Severe Mosaic Virus Disease (SMVD) being found in Cameroun (Ambang *et al.*, 2009).

Even though the nature and severity of the symptoms of a viral disease vary with host cultivar, virus strain and time of infection, certain manifestations (symptomatologies) are usually expressed which help in viral identification. Bashir *et al.* (2002) states that vein banding, interveinal chlorosis, distortion, blistering and stunting of leaves are characteristic of Cowpea Aphid-Borne Mosaic Potyvirus (CABMV). Generally, symptoms expressed on the field by most viral infestations are those of mottling, mosaic or leaf distortion, leaf cupping and necrotic lesions (Bashir and Hampton, 1996). When the field symptoms of two viral infestations (such as those caused by the two potyviruses BICMV and CABMV) are as similar as to be indistinguishable by observation, certain tests such as Enzyme Linked Immno-Sorbent Assays (ELISA) with Monaclonal Antibodies (MAbs) need to be carried out (Huguenot *et al.*, 1994).

2.6 APHID IMPACTS

2.6.1 DIRECT (NUTRIENT DRAIN)

By their nutrition, aphids are very efficient at withdrawing plant sap either from the phloem or the xylem tissues of the plant and when the infestation levels are very high such feeding generally reduces the growth rate of an affected plant and could in extreme cases prematurely kill the plant (Capinera, 2008). As far back as 1989, Wellings *et al.* (1989) publicized the fact that aphids cause 2.6 x 10^6 kg in crop losses globally.

2.6.2 APHIDS AND VIRUS TRANSMISSION

There is a parallel between aphids serving as vectors of viral diseases and mosquitoes vectoring a number of diseases which plague the human race. As in the mosquito, they inadvertently transmit viruses in the course of their feeding activities (Capinera, 2008). *Aphis craccivora* is known to be the most efficient vector of viral infestations on the cowpea crop (Bashir *et al.,* 2002) and it is known to aid the spread of viruses whether of the circulative (persistent) or non-circulative (semi-persistent or non-persistent nature) (Lauffer and Maramarosch, 1983).

Virus movement from an infected plant to a healthy plant is largely dependent on aphid behaviour and is quite complicated as the variables involved are quite numerous. Perring *et al.* (1999) presented a Conceptual Framework (presented below) on this issue. In the framework (shown on the next page), insect feeding refers to plant surface exploration, labial dabbing, test probing and probing of extended durations.

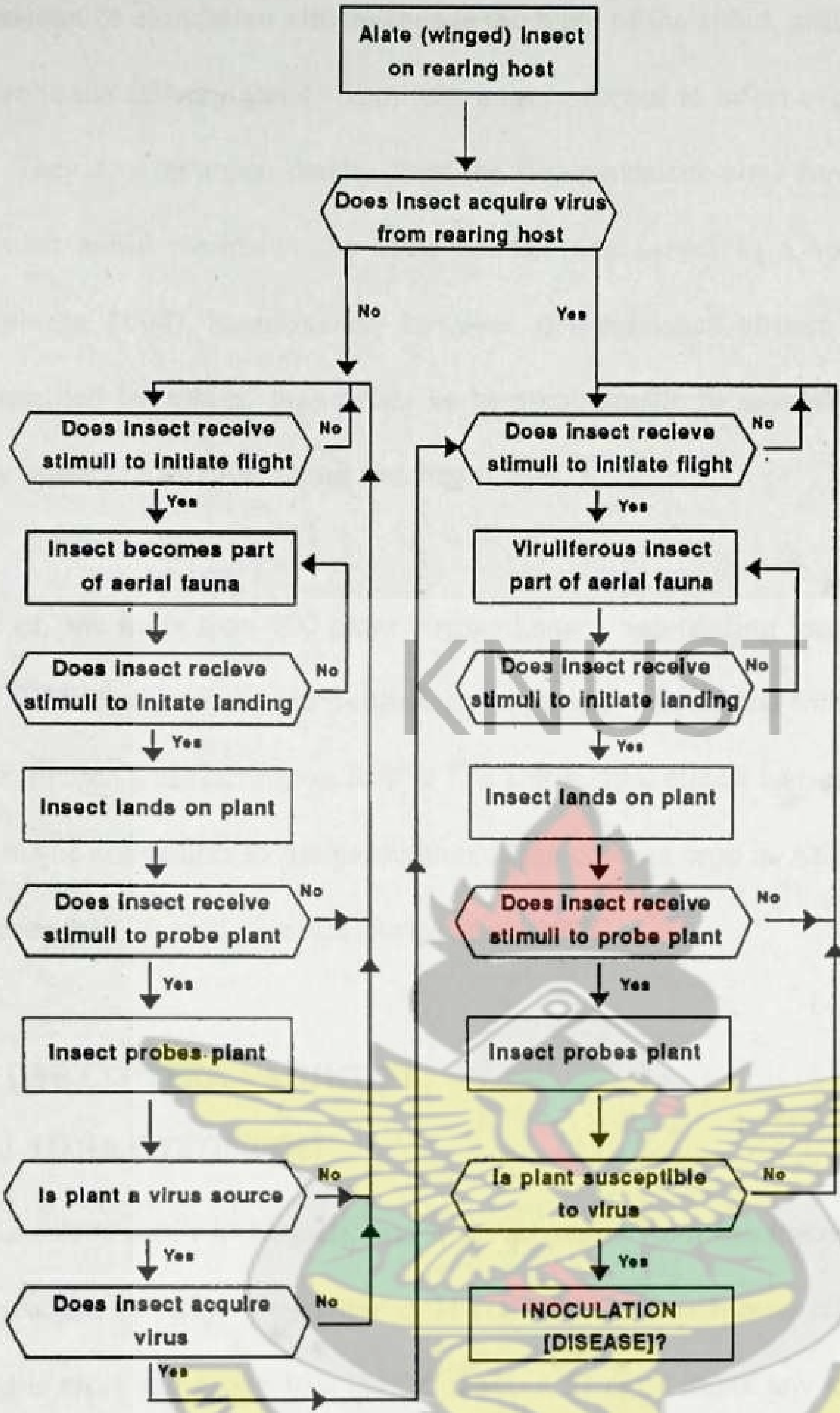


Figure 1: Conceptual model of insect behavioral components involved in viral transmission.

Non-persistent viruses are passed on via stylet-borne transmission and survive only about an hour or so, on the aphids' mouthparts (Capinera, 2008). The efficacy of aphid as a vector for instance of non-persistently transmitted viruses is due to its "food searching" habits, in this case the tendency to land and perform brief epidermal probes (lasting less than a minute) on inappropriate plants. These probes are essential as they help the aphid determine the suitability or otherwise of a host as a food source (Powell and Hardie, 2006).

Persistent or circulative viruses invade the body of the aphid, multiply in the body tissues and move to the salivary glands from where they proceed to infect every plant that the aphid feeds on. They are far more deadly than the non-persistent viral forms in the long term as the infected aphid maintains the virus for life and serves as a sort of reservoir of infection (Capinera, 2008). Paradoxically however, non-persistent viruses account for 75% of viruses transmitted by aphids, may either be by symptomatic or asymptomatic and generally spread very rapidly (Van Emden and Harringon, 2007).

Out of the more than 700 plant viruses known, sap-feeding insects of the Auchenorrhyncha and the Sternorrhyncha are particularly important vectors and transmit more than 380 of them (Van Emden and Harrington, 2007). The detrimental effects caused by viral diseases are one of the major constraints to the production of the cowpea crop in Africa as the crop is susceptible to more than 20 viral diseases (Singh *et al.,* 1997).

2.7 THE COWPEA VARIETIES

2.7.1 TONA (IT87D-2075)

Tona means profit in Dagarti, and is an accession from the International Institute of Tropical Agriculture initially designated as IT87D-2075 and is brown-seeded with a black eye. The plant is erect and grows to a height of about 57 cm without any pubescence on either stem or leaf. The leaf is broad, green in colour and obcuneate in shape. The flower is violet and the mid-vein colour is light green. A medium maturing line, it has a protein content of 22.1%, it flowers 48 to 50 days after planting, matures 71 to 80 days after planting, is resistant and tolerant to most of the cowpea viral diseases such as Cercospora leaf spot and Anthracnose and has a yield potential of 1679 – 2390 kg/ha (Adu-Dapaah *et al.,* 2006).

2.7.2 NHYIRA (IT87D-611-3)

Nhyira means blessing in Akan, and is another accession from the International Institute of Tropical Agriculture initially designated as IT87D-611-3 and is white-seeded with a brown eye. The plant is erect and grows to a height of 53cm without any pubescence on either the stem or the leaf. The leaves are broad, green, borne on long peduncles and are obscuneate in shape. The flower is whitish cream and the mid-vein colour is light green. An early maturing line, it flowers 40 – 43 days after planting, matures 65 – 68 days after planting, is resistant and tolerant to most of the cowpea viral diseases such as Cercospora leaf spot and Anthracnose and has a yield potential of 1058 – 2460 kg/ha. (Adu-Dapaah *et al.*, 2006).

2.7.3 ASETENAPA (IT81D-1951)

Asetenapa means good living in Akan, and is an accession from the International Institute of Tropical Agriculture initially designated as IT8ID- 1951. It is an early maturing variety with a yield potential of 976-1322 kg/ha with a protein content of 22.6% and has the highest phosphorus content (828.0 mg/100g) of the three varieties chosen for this study (Adu-Dapaah *et al.*, 2006).

2.8 THE STANDARD INSECTICIDE (LAMBDA-CYHALOTHRIN/KARATE)

Pyrethroids are a group of man- made insecticides similar to the natural insecticide pyrethrum, which is produced from chrysanthemum flowers. Produced in the late 1970s as an alternative due to the high mammalian toxicity, persistence in the soil and pollution of the environment attributable to most of the insecticides of the time, pyrethroids are generally touted as being less hazardous to humans and animals (Amatobi, 1994) in spite of the LD_{50} (oral) of being 450mg/kg leading to it being tagged moderately hazardous" (Anonymous, 2003). Due to the formulation prior to application (mixed with water or oil) the amount of residues left on surfaces is very small. Additionally, breakdown by sunlight and other chemicals occurs in the environment leading to low persistence in the environment of only one or two days. (Anonymous, 2007). Karate is the marketing name for a synthetic pyrethroid that contains lambda-cyhalothrin as it active ingredient, characterized by a rapid knockdown and known effectiveness against a number of insect pests of vegetable and tree crops. Being photo-stable, it has both contact stomach poisoning effect, with some repellent properties (Anonymous, 2003).

CHAPTER THREE

MATERIALS AND METHODS

3.1 STUDY AREA

The study was conducted at a farm of the Wenchi Farm Institute in the Wenchi Municipality of the BrongAhafo Region of Ghana (**Figure 2**) during the minor cropping season, which is from September to December, 2008. The farm has a gentle slope and well drained.

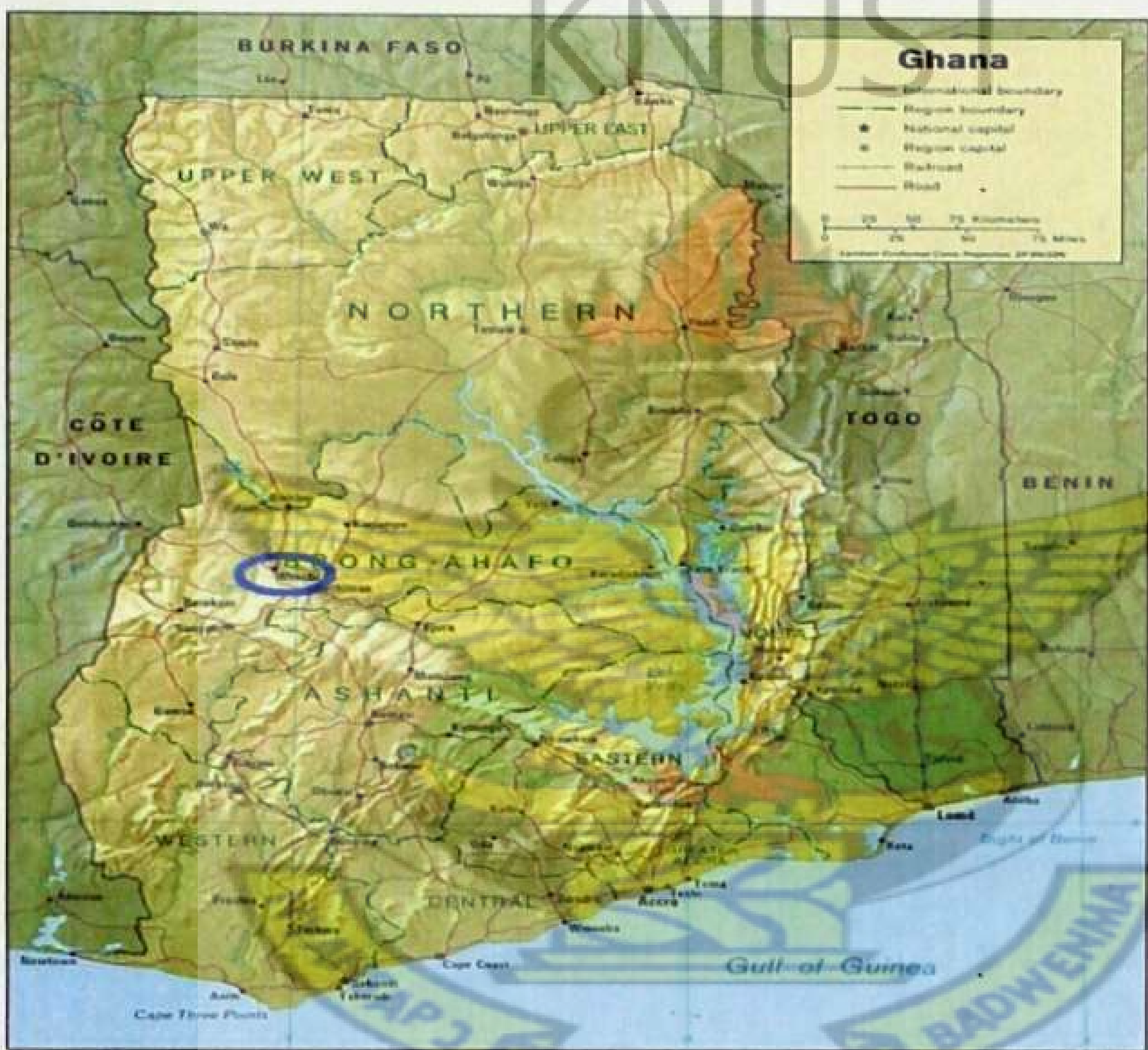


Figure 2. Map of Ghana showing location of Wenchi (Blue Circle).

Wenchi lies between latitudes 7^0 27" N and 8^0 3" N, and longitudes 1^0 30" N and 2^0 36" W. The Municipality is bounded in the North by the Black Volta and Bole District; in the East by Techiman Municipality and Kintampo south District; in the South by Sunyani Metropolis and in the West by Jaman/ Berekum Districts and Tain District (figure 3).The Wenchi Municipality lies within the Tain Basin (Environmental Audit And Institutional Strengthening in Wenchi District, 1996).

The Municipality lies within the transitional zone, i.e. between the forest belt of the south and savannah in the North. The common soil textures are sandy loam with some areas being clayey loam in the valley areas. Forest ochrosols are also located in the forested areas of the municipality.

Temperatures in Wenchi are relatively higher than in other parts of the BrongAhafo Region. The mean monthly temperature in the Municipality is about 30^0 C with April being the hottest month. The rainy season occurs from April to November with peaks occurring between the end of March and July, and between September and October. The annual rainfall varies between 1,300mm and 1,500m. The harmattan winds blow across the Municipality from November to March/April. Appendices A and B present the rainfall data and temperature figures respectively during the period of the study obtained from the Wenchi Meteorological Station.

Agriculture is the mainstay of the economy of Wenchi with the rate of economic development being closely linked with the performance of agriculture. Agriculture, including livestock production, provides the main source of employment for the people of Wenchi Municipality.

Major crops grown are yam, cocoa-yam, plantain, maize, cassava and vegetables. Cowpea is a minor crop grown in the Municipality (Environmental Audit And Institutional Strengthening in Wenchi District, 1996).

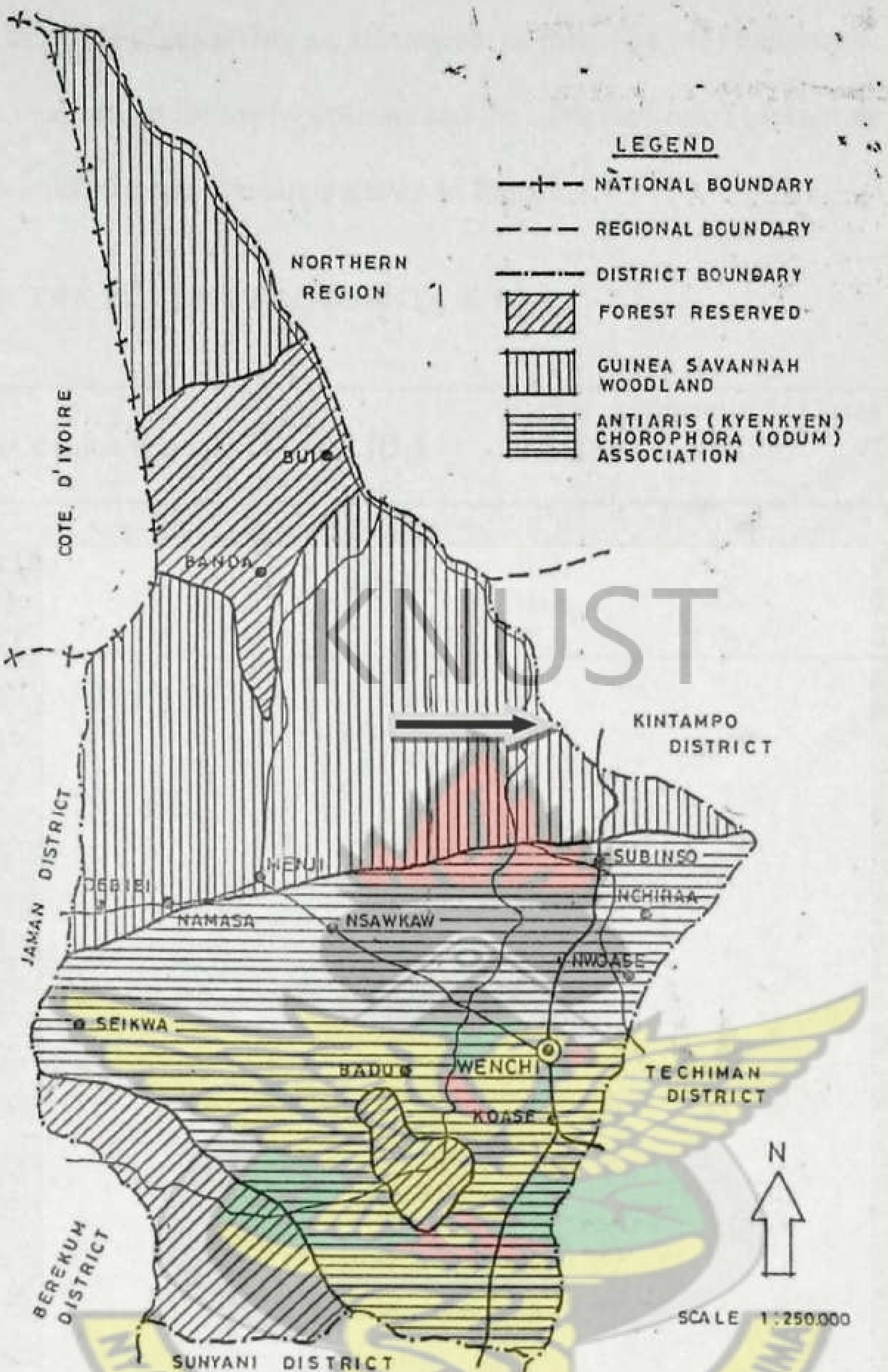


Figure 3. Map of Wenchi Municipality showing study site by black arrow.

3.2 EXPERIMENTAL DESIGN AND LAYOUT

The field used was set up in Randomized Complete Block Design (RCBD) with a total plot size of 436.8 m^2. Two factors – Insecticide doses (A) and Cowpea varieties (B) as illustrated below (Table 1). Insecticide doses (A); 0.2 ml, 0.4ml; 0.6ml, 0.8ml were designated D_1 to D_4 with the control tagged D_5. The cowpea varieties (B) utilized was Tona (T), Nhyira (N) and Asetenapa (A) as shown below (Table 1).

Thus, each experiment was a 5x3 factorial one with fifteen (15) treatments which were replicated three (3) times giving a total number of forty five (45) treatments. Fifteen 5.4x 1.6 m plots were marked out for every replicate and the three replicate blocks were separated by a 1m border. The experimental layout is shown in **Figure 4**.

TABLE 1: TREATMENT FACTORS (A & B)

Factor B (Cowpea varieties)	**Factor A** (Insecticide Doses in mls)				
	0.2 (D_1)	0.4 (D_2)	0.6 (D_3)	0.8 (D_4)	Control (D_5)
Asetenapa (A)	AD_1	AD_2	AD_3	AD_4	AD_5
Nhyira (N)	ND_1	ND_2	ND_3	ND_4	ND_5
Tona (T)	TD_1	TD_2	TD_3	TD_4	TD_5

3.2.1 EXPERIMENTAL LAYOUT

A total land size of 436.8 m^2 was used for this study and this was divided into individual plots with a size of $9m^2$. All plots were separated by (1.5m) buffer zone. A spacing of 60cm x 20cm was adopted for each plot and there were 80 plants on each plot.

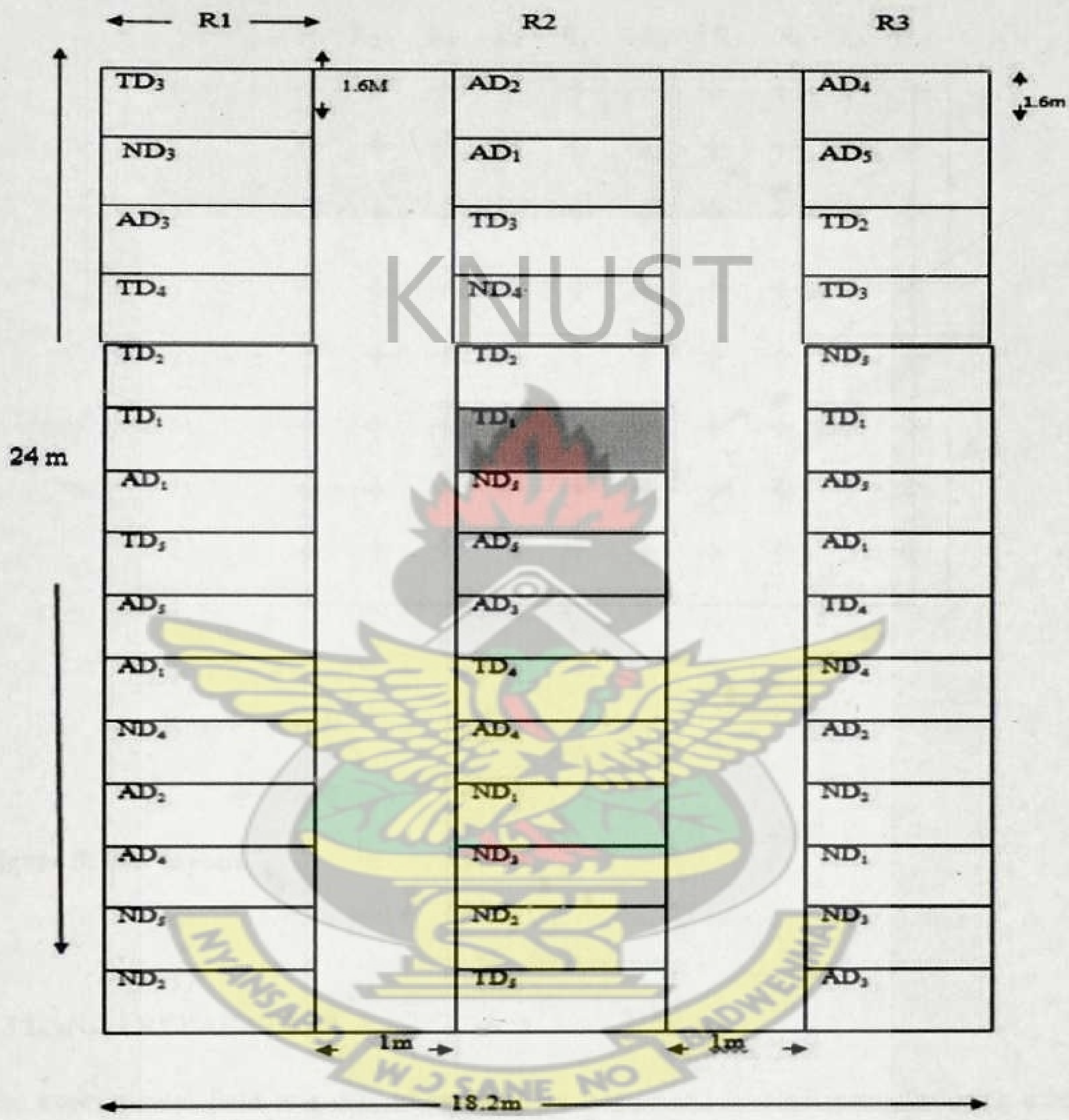


Figure 4. Experimental layout

Figure 5 below illustrates the planting of the cowpea crop in the plots with the highlighted plot TD_1 from Figure 4 above serving as a sample.

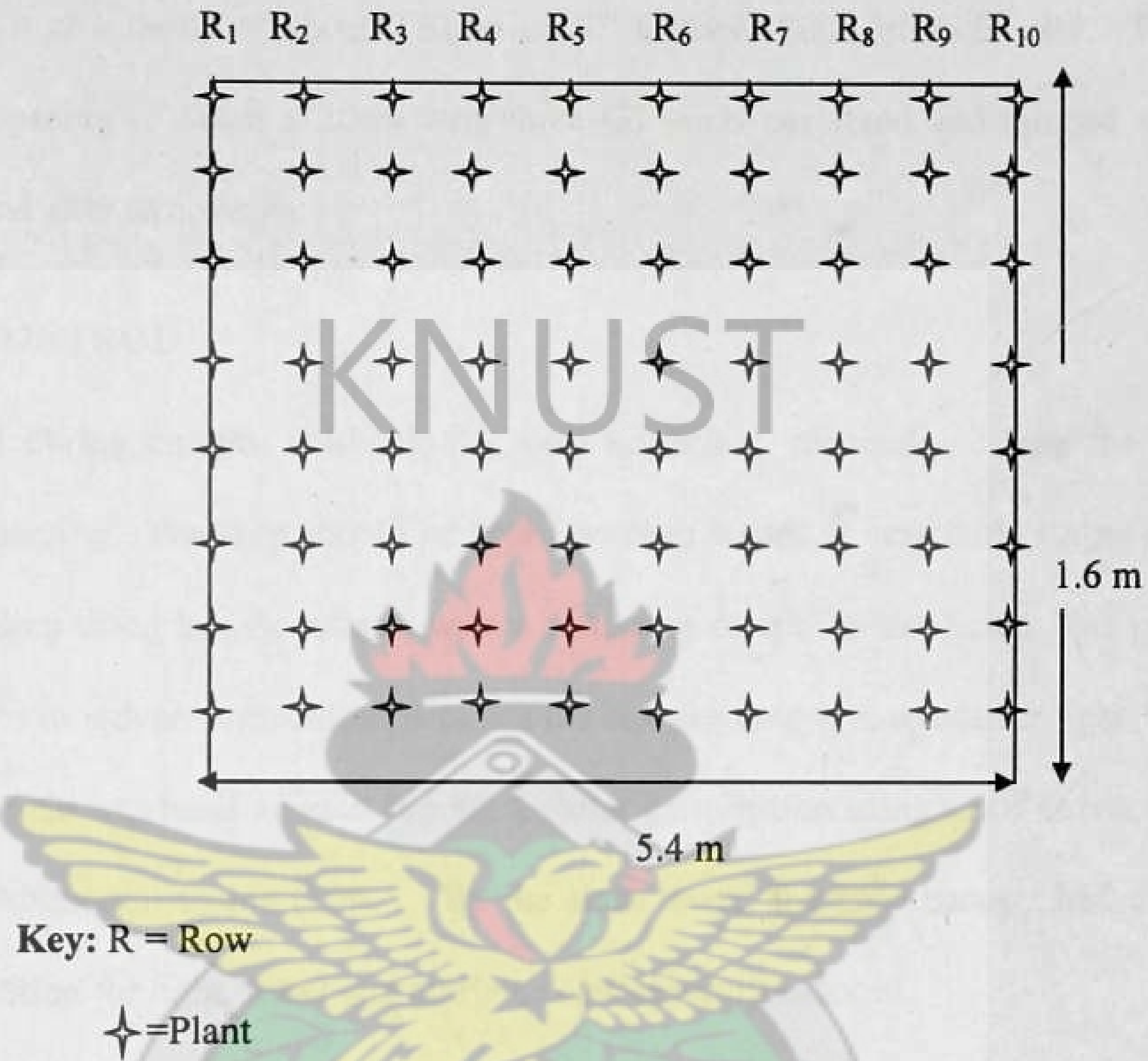


Figure 5: Plot layout

3.3 LAND PREPARATION

The experimental field was disc ploughed by a tractor and leveled manually using a hoe to facilitate plot layout and subsequent planting.

3.4 SOWING

Three varieties of cowpea namely Nhyira (IT87D-6113), Tona (IT87D-2075) and Asetenapa (IT81D-1951) were obtained from the Crops Research Institute (CRI) of the Council for Scientific and Industrial Research (CSIR), Fumesua– Kumasi. The three cowpea varieties were manually sown at a depth of about 3.81cm on 7th October 2008 in moist soil. They were planted at a spacing of 60cm x 20cm with three (3) seeds per stand and thinned to two (2) plants per stand after two weeks.

3.5 WEED CONTROL

Weed control during cowpea cultivation is very important, especially during the first four weeks after planting. The crop should be kept free from weeds at very early stages of growth by hand weeding using hoe or cutlass; with a cultivator or with a weedicide. The purpose of weed control is to reduce competition between the cowpea crop and weeds for light, water and nutrients.The field was hand weeded two weeks after germination using a hoe as recommended by Cowpea Production Guide (1990). By the sixth week, the crop canopy had closed and weeds competition for light, water and nutrients consequently reduced.

3.6 INSECTICIDE TREATMENT

The treatments consisted of four (4) different doses of foliar insecticide, Lambda-cyhalothrin (Table 1). The insecticide treatments were designated as D1 to D4 respectively with the control as D5.

3.7 WEEKLY INSECT COUNTS

The numbers of infested plants were noted weekly by counting the number of plants infested by aphids one week after germination. The method of Stiling (1985) point counting of plants infested by aphids was used to determine the level of infestation (Plate 1). The stand of plants in the plot was visually searched every week to establish the number of plants infested as outlined by William and Marcos, (1994). The weekly counting was done for eight (8) weeks throughout the growth period. At the end of the eighth week, the total number of plants infested was recorded. A measure of the insect population size was obtained by this method. However, this method did not provide absolute values of the insect population.

Plate 1: Counting the number of plants infested by *Aphis craccivora*.

3.8 INSECTICIDE TREATMENT

Two weeks after germination, the plots were sprayed with four different doses of lambda-cyhalothrin insecticide, namely: 0.2ml, 0.4ml, 0.6ml and 0.8ml. Some plots were not sprayed with the Lambda-cyhalothrin insecticide. Ordinary water was used to spray and were used as controls.The manufacturer's recommendation was 1000ml (1litre) insecticide/ ha and 30ml / knapsack (15litres). By simple proportion, the various doses gave 2ml is to 1litre of water, 3ml is to 1.5 litres of water, 5ml is to 25 litres of water and 6ml is to 3 litres of water respectively for the 15 plots in each replicate. The Emulsifiable Concentrate (E.C) formulations were applied with pressurized air low volume knapsack (CP 15) sprayers fitted with a cone nozzle (plate 2). All the doses were applied four times at two weeks intervals. During the treatment applications, a polythene sheet (1metre high) was held between the plot boundaries to reduce the drift from plot to plot.

Plate 2: Applying Insecticides

The parameters studied in this work were the number of plants infested by *A.craccivora* treated with different dose levels of lambda-cyhalothrin insecticide, number of pods, pod weight and finally the grain yield of the three different cultivars of cowpea. Below is a picture of a section of the farm four weeks after planting (Plate 3). The treatment levels of insecticide applied were; D_1= 0.2ml, D_2 =0.4ml, D_3 = 0.6ml, D_4 =0.8ml and D_5 = control as indicated in **Table 1.**

PLATE 3: **A section of the farm at 4-weeks post-planting.**

3.9 YIELD DETERMINATION

Harvesting was done by hand picking three (3) times after eight weeks of germination. The first picking was carried out on the 14th of December, 2008 and subsequent picking every five days. Labeled brown envelopes were used to store the harvested pods. Counting of pods was done at every harvest to determine the total number of pods per plot or treatment. Weight of the pods was determined by the use of Kain Chung scale. The pods were then threshed. Each plot or treatment harvested was put in a sack and the mouth tied and beaten. The shells were then separated from the grains. The grains were subsequently weighed to determine the final yield.

3.10 DATA ANALYSIS

All statistical computations were done with the Sigma Plot Statistical Package (Version 11.0). Possible effects of the different chemical doses used on the three cowpea varieties were verified using One-Way Analysis of Variance (ANOVA) at 95 % level of significance. Significance or otherwise of the means was determined using the Holm-Sidak Pairwise Comparison Test.

CHAPTER FOUR

RESULTS

4.1 WEEKLY APHID INFESTATION OF TREATMENTS

The weekly aphid infestation for 0.2ml by lambda-cyhalothrin treatments are presented in Figure 6. There was no insect infestation on Nhyira from germination through to week-4. From week-4 there was some infestation. This rose up through week-5 and peaked with mean infestation value of about 3.5 plants at week-6. There was however a decline from week-6 through to week-8 with a value of 1.

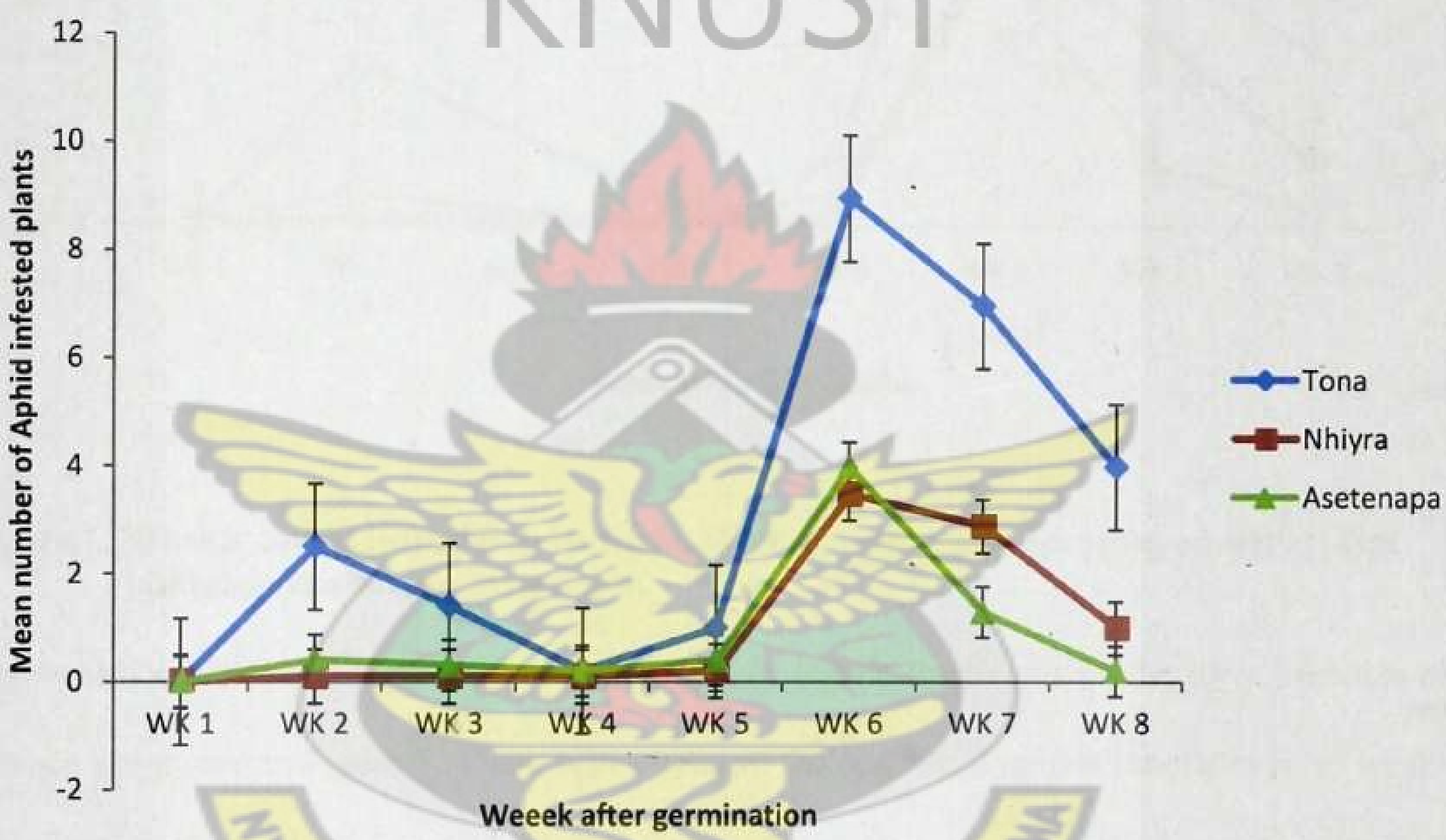


Figure 6: Weekly aphid infestation levels on three cowpea varieties sprayed with 0.2ml lambda-cyhalothrin insecticide.

Asetenapa recorded some insect infestation right from week-1 after germination to week-8. Between week-1and week-5 mean values of insect infestation were below 1. Then from week-5 there was a sharp rise with peak mean value of 4. This mean value was decreased to a value of 3 at the eighth week Figure 6.Tona also recorded infestations throughout the experimental period. From week one there was a rise in infestation. This peaked at week-2 with a mean value above 2. There was, however, a gradual decline through week-3 to week-4. There was again a rise from week four to week five, then a very sharp rise to a mean value of 9 at week six and started to decrease to a value of 4 at week eight Figure 6.

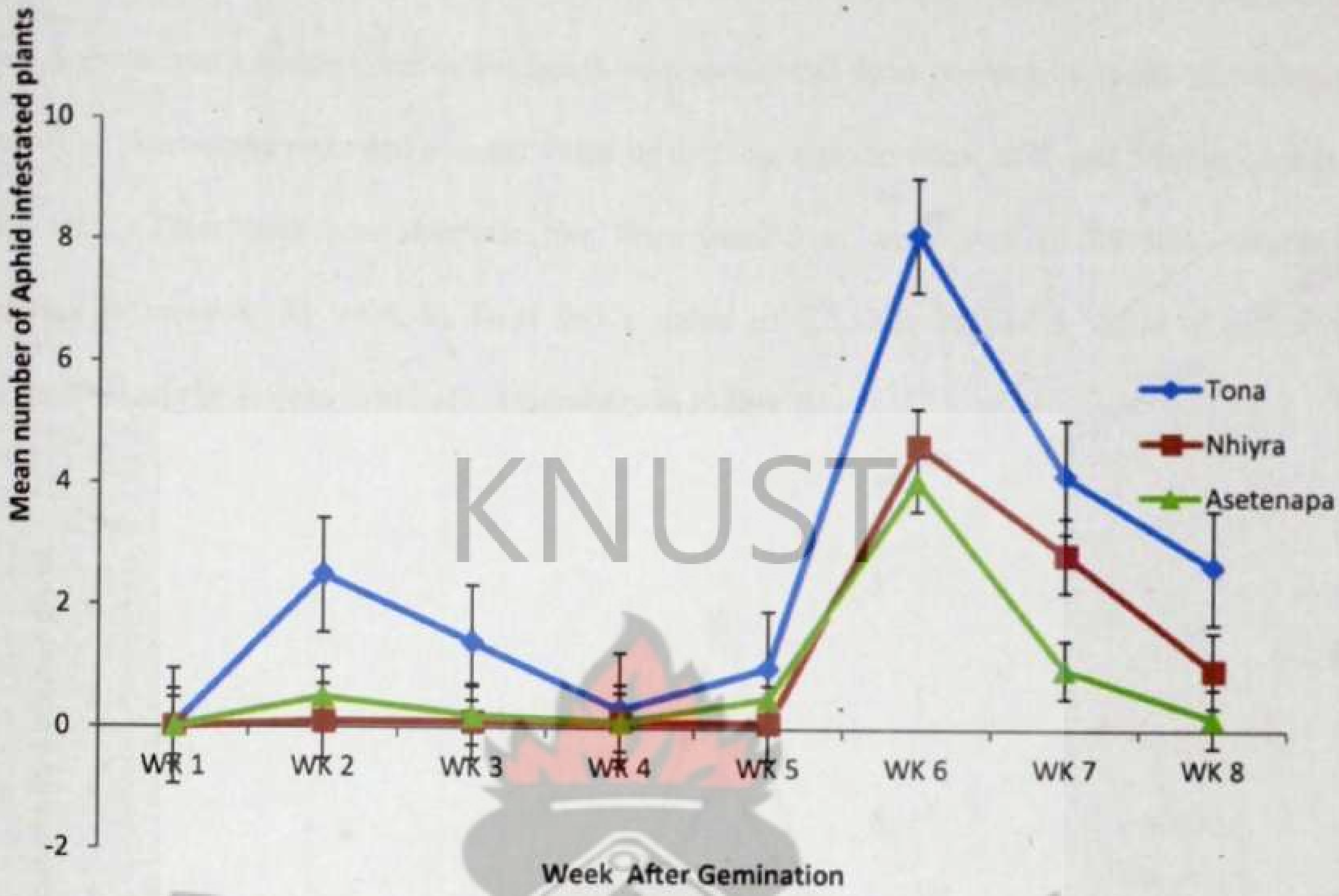


Figure 7: Weekly aphid infestation levels on three cowpea varieties sprayed with 0.4ml lambda-cyhalothrin insecticide.

The weekly infestation levels for 0.4ml lambda-cyhalothrin treatments on the three varieties of cowpea are shown in Figure 7. There was a general fluctuation of aphids' numbers from week-1 to week-8. There was a general increase in aphids infestation and reached a peak at week-2 and the sixth week. At week-2, Tona variety peaked at a value of 1.9, Asetenapa variety had a value of 0.5 and Nhyira variety had a value of 0.3 from the sixth week there was a drastic decrease in aphids' numbers of all the cowpea varieties. At week-8, Tona variety had a value of 2, Nhyira variety had a value of 1.3 and Asetenapa variety had a value of 0.4.

Aphids' infestations of 0.6ml lambda-cyhalothrin insecticide treatment on the three cowpea verities (Tona, Nhyira and Asetenapa) are presented in Figure 8. Between week-2 and week-5 the three cowpea varieties recorded mean values of insect numbers less than 1. Then from week-5 there was a sudden rise in the insect numbers of the three cowpea varieties all peaking at week-6. Asetenapa recorded a mean value of 8, Tona a mean value of 4 and Nhyira a mean value of 2. Then there was sharp decline from week-6 to week-7 of all the three cowpea varieties to week-8. At week-8, Tona had a value of 1.5, Nhyira had a value of 1.8 and Asetenapa had the lowest value of 1.4 numbers in Figure 8.

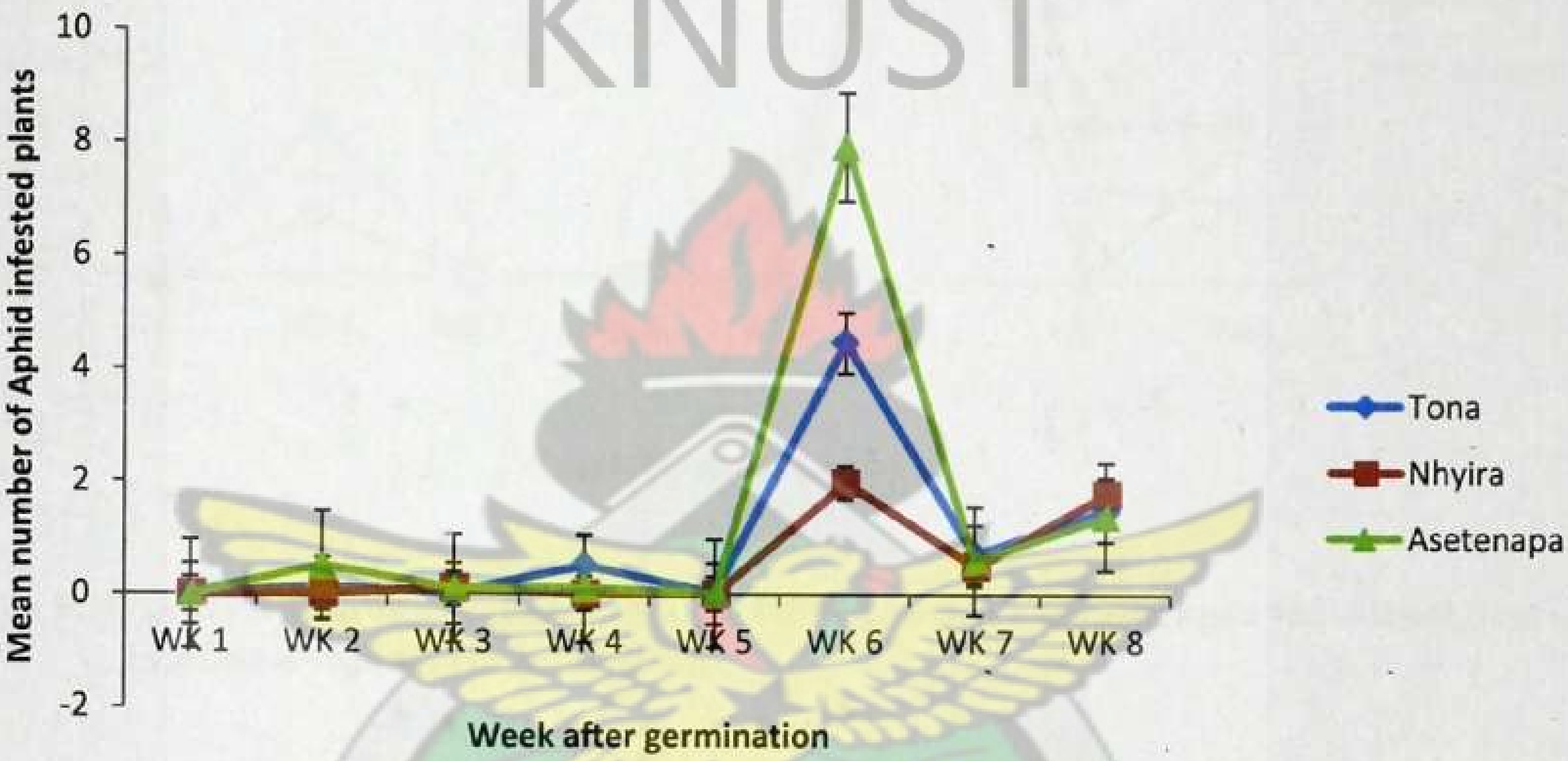


Figure 8: Weekly aphid infestation levels on three cowpea varieties sprayed with 0.6ml lambda-cyhalothrin insecticide.

The weekly varietal aphid infestation levels for 0.8 ml lambda-cyhalothrin treatment are indicated in Figure 9.Tona variety recorded a mean value of 1 at week-2 with a sharp drop to 0 at week-3 to 4, and there was a gentle rise from 0 to less than 0.5 at week-5. This was followed by a sharp rise at week-5to peak of 3 at week-6. The numbers dropped to 0.6 and 0.5 at week-7 and 8 respectively. Similarly, Nhyira recorded mean values below 0.5 from week-1 to week-5. At week-5 the insect infestation mean value shot up to 4 then dropped to 1 at week-7 and 8. For Asetenapa, there was no score of insect infestation from week-1 up to week-5. There was however a rise in insect infestation level from week-5 which peaked at week-6 with a mean value of 3.6 and then dropped to mean value of 0 at week-7 and again rose to mean value of 0.5 at week-8.

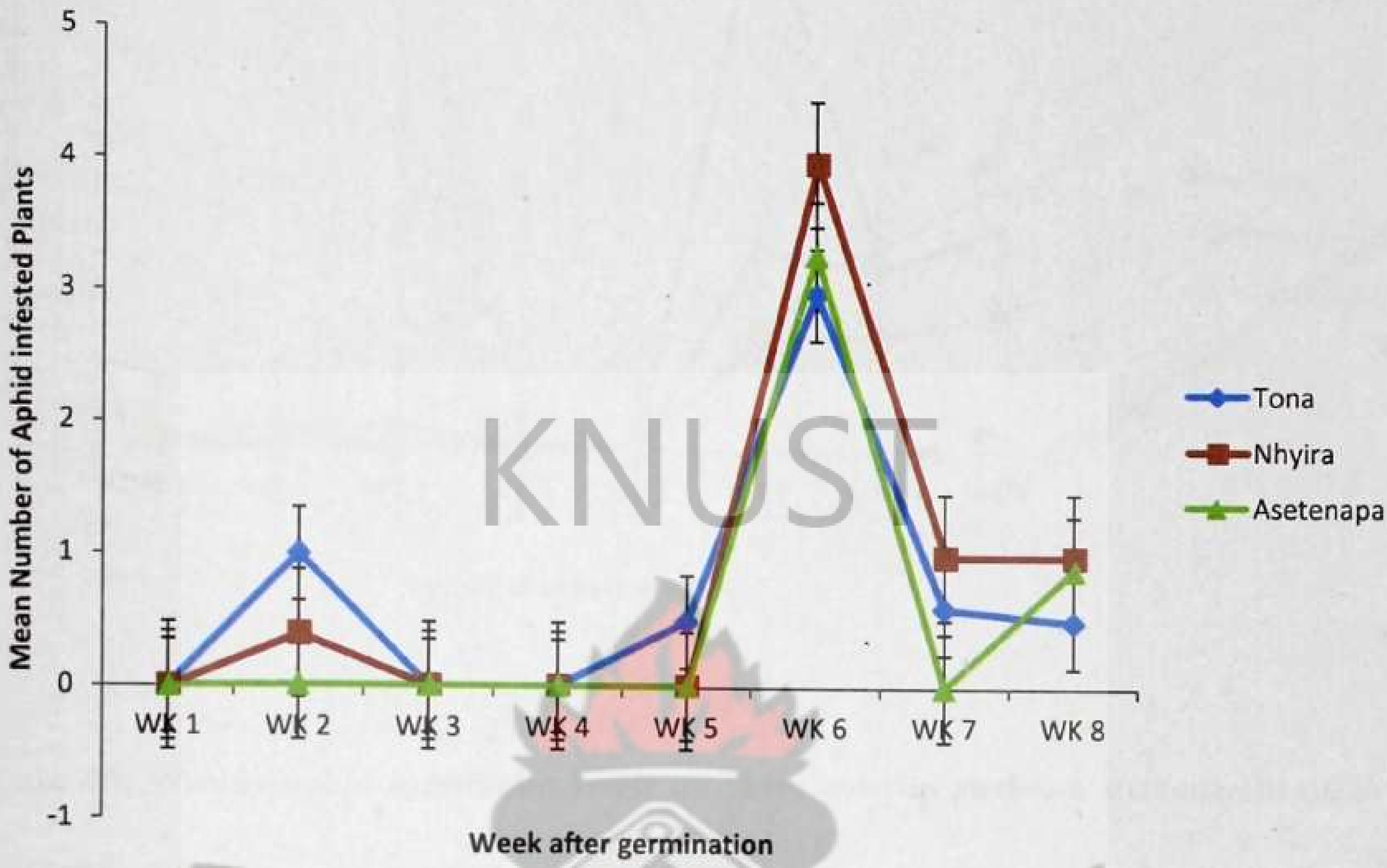


Figure 9: Weekly aphid infestation levels on three cowpea varieties sprayed with 0.8ml lambda-cyhalothrin insecticide.

From Figure 10 presents the weekly aphid infestation levels for untreated (control) treatment of the cowpea varieties from week-1 to week-8. There was aphid infestation throughout the 8 weeks period. The highest level of insect infestation was recorded at week-6 by Asetenapa variety with a mean value of 25. This dropped to a mean value of 9 at week-7 then rose again to a mean value of 12 at week-8.

Tona variety followed a similar trend but with relatively lower values. The level of insect infestation rose from 0 at week-5 to 9 at week 6 and week 7. There was a little rise from week-7 to week-8 with a mean value of 10. Nhyira recorded the lowest insect numbers with a gentle rise from week-5 through week-6, week-7 and week-8 at these mean values of 5, 5.1 and 6 respectively.

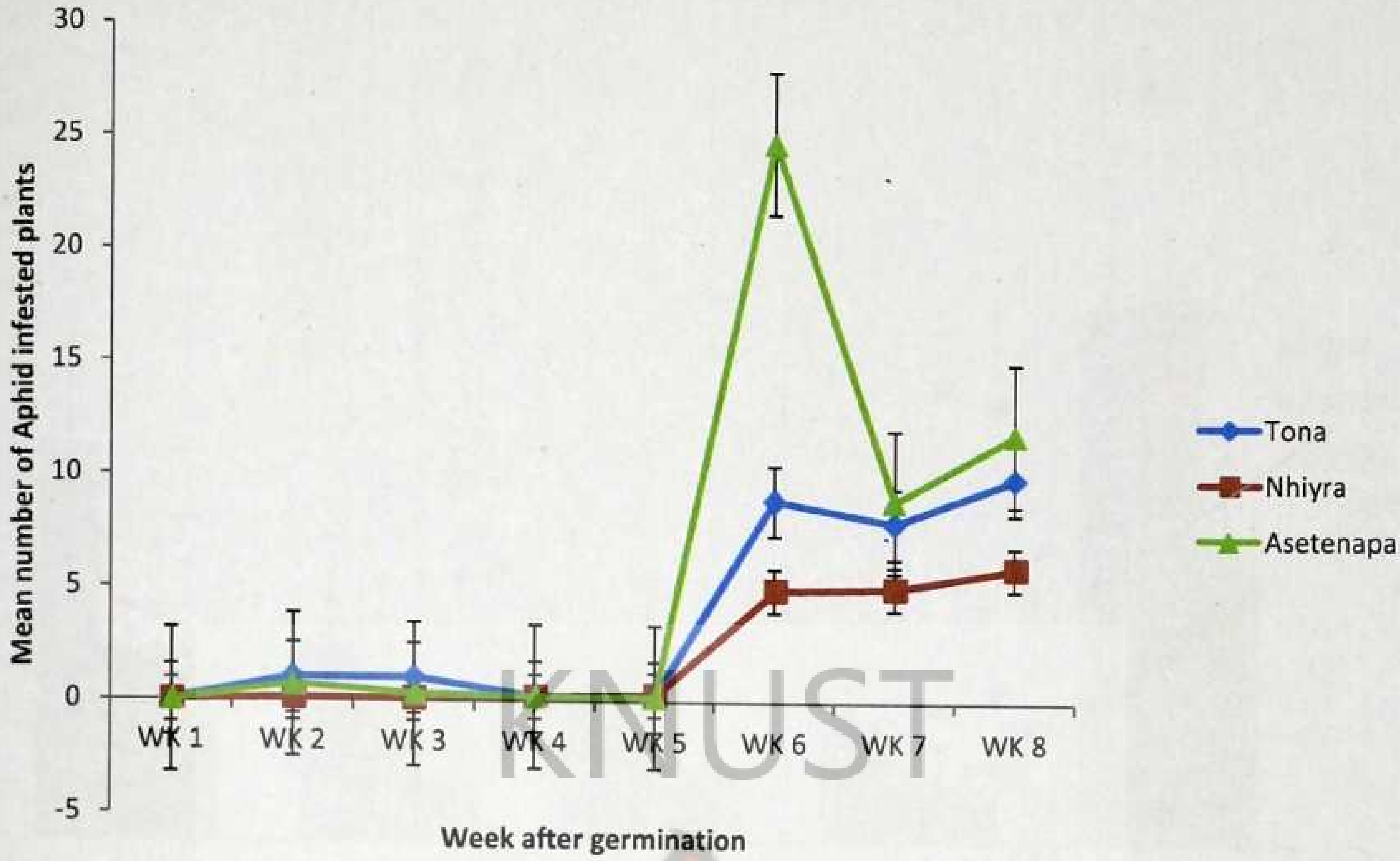


Figure 10: Weekly aphid infestation levels on three cowpea varieties without chemical treatment.

4.2 EFFECTS OF TREATMENTS ON LEVEL OF APHID INFESTATION OF THREE COWPEA VARIETIES

Results of the effects of the different treatment of the three cowpea varieties by lambda-cyhalothrin on the level of Aphid infestation are presented in Figure 11. The mean values for the treatment of 0.2 ml lambda-cyhalothrin for the three varieties, Tona recorded the highest mean aphids numbers (23 ± 6.25) as against Asetenapa and Nhyira varieties with (11 ± 2.88) and (6.67 ± 3.18) respectively (Appendix C). There was a significant difference between the Tona variety and the other two varieties but no significant difference between Asetenapa and Nhyira ($P = 0.05$).

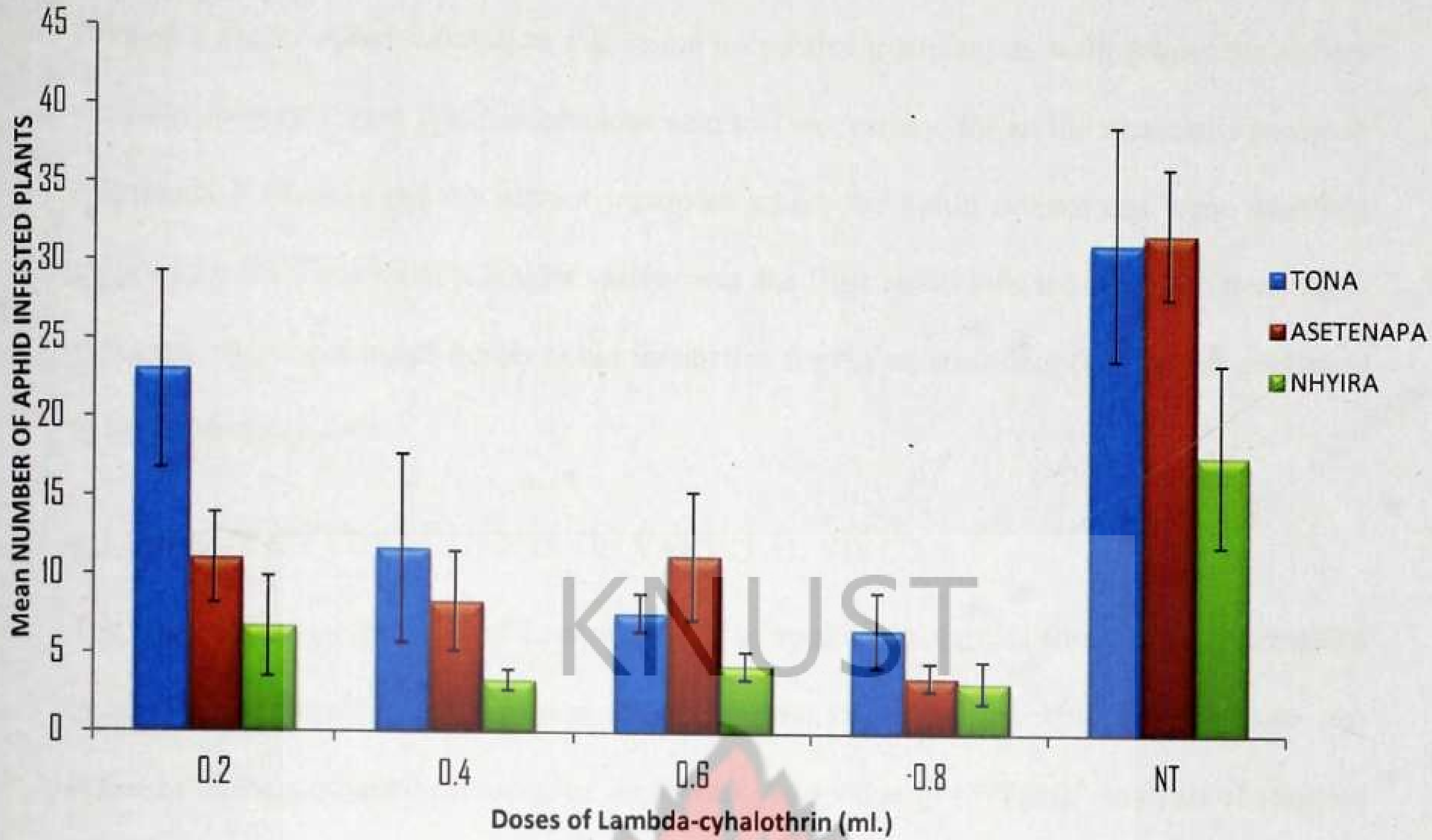


Figure 11: Effect of Different doses of Lambda-cyhalothrin on the Level of Aphid Infestation in three cowpea varieties.

For treatment 0.4ml, Tona variety recorded the highest aphid infestation (11.67±6.00) and the least being Nhyira (3.33±0.67). There was however, a decline in the level of infestation as compared to treatment with 0.2ml. However, treatment with 0.6 ml had Asetenapa variety recordding the highest mean infestation value of (11.33± 4.09) Nhyira as the least (4.33± 1.33).For treatment with 0.8ml Tona variety recorded the highest (6.67±2.40), Asetenapa (3.67±0.88) and Nhyira (3.33±1.33) the least.

The control recorded the infestation for Tona variety (31.67±7.53), Asetenapa recorded the highest (32.33±4.7) and Nhyira recorded the least (18.00±5.85). There was however no significant differences between Tona and Asetenapa, Asetenapa and Nhyira but between Tona and Nhyira (P = 0.05).

The effect of different treatments of Lambda-cyhalothrin (0.2ml, 0.4ml, 0.6ml, 0.8ml and no treatment) on the level of aphid infestation in the three cowpea varieties; Tona, Asetenapa and Nhyira are presented in Figure11 . Generally, Tona variety showed a higher level of aphid infestation in all the treatment except in treatment 3 (0.6ml) where Asetenapa variety rather showed a higher aphid infestation and in the no control treatment as well. Asetenapa variety similarly showed higher aphid infestations next to Tona variety, for all the treatments except in treatments 3 (0.6ml) and no control treatment where the aphid infestations were relatively higher than the Tona variety,Nhyira variety was the least aphid infested in all the treatments. However, there was much higher aphid infestation for the no treatment (control) as compared to the other treatments.

4.3 EFFECT OF TREATMENTS ON VARIETAL YIELD

The mean values of the yield of Tona variety of cowpea of the various treatments are presented in table 2. Treatment with 0.6ml recorded the highest yield (717gm) while the treatment with 0.2ml of lambda-cyhalothrin recorded the lowest yield value of (375gm). Analysis of variance (ANOVA) indicated that treatment three (0.6ml) showed significant difference ($P = 0.008$). All the other treatments did not show any significant difference at the same level. This could mean that treatment three (0.6 ml) was more effective in managing the aphids hence the higher yield.

Table 2: **Effect of Lambda-cyhalothrin treatment on yield of Tona**

Replicates	Lambda-cyhalothrin Treatments 0.2ml	0.4ml	0.6ml	0.8ml	Control NT
R1	300 g	400 g	400 g	400 g	250 g
R2	750 g	750 g	1000 g	750 g	425 g
R3	600 g	650 g	750 g	650 g	450 g
Mean	**550g**	**600 g**	**717 g**	**600 g**	**375 g**
G/M^2	63.65741	69.44444	82.94753	69.44444	43.40278
t/ha	0.213191	0.231481	0.276620	0.231481	0.144676

Key: NT – No Treatment.

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05

Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant
0.6 vs. NT	341.667	5.302	<0.001	0.005	Yes
0.8 vs. NT	225.000	3.492	0.008	0.006	No
0.4 vs. NT	225.000	3.492	0.008	0.006	No
0.2 vs. NT	175.000	2.716	0.026	0.007	No
0.6 vs. 0.2	166.667	2.586	0.032	0.009	No

The mean yield values of Asetenapa cowpea variety are shown in Table 3. Treatment with 0.8 ml lambda-cyhalothrin recorded the highest yield of 766g, treatment with 0.4ml followed with 733g, treatment with 0.6ml obtained 633g, then treatment with 0.2ml had 533g while the control recorded the least of 358g. Treatments 0.8 ml, 0.6ml and 0.4 ml were significantly different compared to treatments with 0.2ml and the control.

Table 3: Effect of Lambda-cyhalothrin treatments on yield of Asetenapa

Replicates	Lambda-cyhalothrin Treatments 0.2ml	0.4ml	0.6ml	0.8ml	Control NT
R1	350 g	600 g	350 g	550 g	175 g
R2	600 g	850 g	900 g	850 g	400 g
R3	650 g	750 g	650 g	900 g	500 g
Mean	**533g**	**733 g**	**633 g**	**766 g**	**358 g**
G/M^2	61.7284	84.87654	73.30247	88.73457	41.47377
t/ha	0.205632	0.282793	0.244213	0.295524	0.138117

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05

Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant
0.8 vs. NT	408.333	5.783	<0.001	0.005	Yes
0.4 vs. NT	375.000	5.311	<0.001	0.006	Yes
0.6 vs. NT	275.000	3.895	0.005	0.006	Yes
0.8 vs. 0.2	233.333	3.304	0.011	0.007	No
0.4 vs. 0.2	200.000	2.832	0.022	0.009	No
0.2 vs. NT	175.000	2.478	0.038	0.010	No
0.8 vs. 0.6	133.333	1.888	0.096	0.013	No
0.4 vs. 0.6	100.000	1.416	0.194	0.017	No
0.6 vs. 0.2	100.000	1.416	0.194	0.025	No
0.8 vs. 0.4	33.333	0.472	0.649	0.050	No

The yield records of Nhyira cowpea variety is presented in Table 4. Treatment 0.8ml obtained the highest grain yield of 550g, treatment 0.2ml had 433g, treatment 0.6ml got 400g and treatments (0.4ml) and control recorded 383g and 283g respectively in a descending order. The statistical analysis revealed that there was no significant differences among the treatments except between treatments (0.8ml) and the control (P = 0.022).

Table 4: Effect of Lambda-cyhalothrin treatments on yield of Nhyira

Replicates	Lambda-cyhalothrin Treatments 0.2ml	0.4ml	0.6ml	0.8ml	Control NT
R1	400 g	350 g	250 g	550 g	200 g
R2	550 g	400 g	600 g	600 g	350 g
R3	350 g	400 g	350 g	500 g	300 g
Mean	**433 g**	**383 g**	**400 g**	**550 g**	**283 g**
G/M^2	50.15432	44.36728	46.2963	63.65741	32.79321
t/ha	0.167052	0.147762	0.154321	0.212191	0.109182

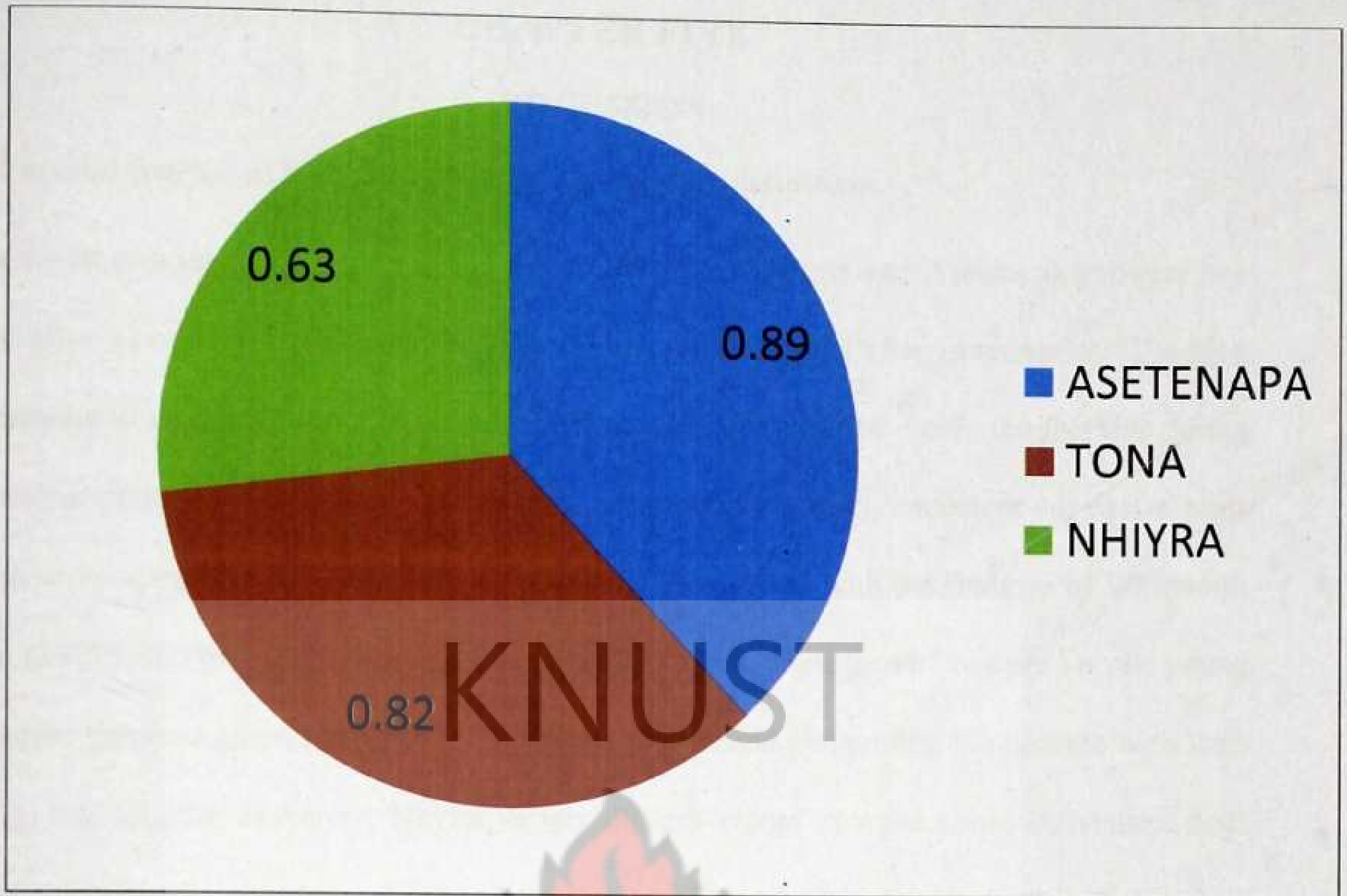
All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05 Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
0.8 vs. NT	266.667	4.507	0.002	0.005	Yes
0.8 vs. 0.4	166.667	2.817	0.023	0.006	No
0.2 vs. NT	150.000	2.535	0.035	0.006	No
0.8 vs. 0.6	150.000	2.535	0.035	0.007	No
0.8 vs. 0.2	116.667	1.972	0.084	0.009	No
0.6 vs. NT	116.667	1.972	0.084	0.010	No
0.4 vs. NT	100.000	1.690	0.129	0.013	No
0.2 vs. 0.4	50.000	0.845	0.423	0.017	No
0.2 vs. 0.6	33.333	0.563	0.589	0.025	No
0.6 vs. 0.4	16.667	0.282	0.785	0.050	No

Table 5. The impact of Aphids on the yield of the cowpea cultivars

Cowpea cultivars	Mean Number Of Plants Infested By Aphids	Yield values (T/ha)
Tona	34	0.89
Asetenapa	49	0.82
Nhyira	18	0.63



The influence of lambda-cyhalothrin treatments on the total cowpea varietal yields are presented in table 5. The highest dose regimen of 0.8 ml gave the best yield for two out of three varieties. *Asetenapa* had the highest yield of (0.89 t/ha) while with an unexpected discrepancy in the trend as the 0.6 ml dosage rather gave the highest yield for *Tona* (0.69 t/ha). Then Nhyira with the least yield of (0.63t/h) at 0.8ml. ANOVA (Appendix E) indicated (rather disappointingly) that there were no significant differences between the yields obtained throughout the project.

CHAPTER FIVE

DISCUSSION

5.1 Varietal treatment with 0.2ml to 0.8ml lambada-cyhalothrin

There was cowpea aphid (*Aphis craccivora*) infestation of Tona and Asetenapa varieties one week after germination which reached the first peak two weeks after germination. The high cowpea aphid infestation from one week after germination might be due to the fact that during the earlier period of germination and growth, the plants had fresh, succulent vegetative parts which were nutritious and attractive to the insects. This agrees with the findings of Whitworth *et al,* (2009) who found that cowpea aphid feed on the under surface of cowpea leaves, young succulent terminal growth parts by piercing plant tissue and penetrating the phloem with their needle like mouths. However, Nhyira variety did not record cowpea aphid infestation from germination to the fourth week after germination. The possible explanation is that aphids appear to select the cultivar of plant most suitable for reproduction.

Lambda-cyhalothrin insecticide (0.2ml) was used as a foliar spray in the second week after germination which reduced the cowpea aphid infestation starting from the second week to the fourth week (Fig. 7). The cowpea aphids are soft bodied insects and foliar sprays had earlier direct contact with the aphids. Lambda-cyhalothrin is a pyrethroid insecticide with very high activity and action. This might have accounted for the quick reduction in the aphid infestation from the second week to the fourth week. After the reduction of the aphid infestation there was a gradual increase in aphid infestation that reached a peak at week six. Despite the use of foliar spray of lambda-cyhalothrin on all the three varieties at week four, the aphid population gradually increased to reach a peak at week six. The cowpea plants might have developed thick vegetative cover such that during the period of foliar spraying, the insecticide could not get into direct contact with the aphids that are usually found on the underside of leaves. Also the cowpea aphids might have begun to distort and curl the leaves making it difficult to control them because the curled leaves shelter the aphids from the foliar sprays.

According to Leahey (1985), pyrethroid insecticides undergo rapid degradation on foliage resulting in low doses of residues getting to target insects. This could also account for the gradual increase in aphid population instead of a decrease. However, the use of foliar spray during the sixth week caused a rapid decline in the aphid infestation on all the three varieties. Apart from the effect of the insecticides, the vegetative parts of the cowpea plants were now hardened and not succulent for fast development of aphids. Therefore fewer nymphs were produced on the older leaves and aphid population was decreasing as the cowpea plants were maturing.

On the whole, 0.2ml lambda-cyhalothrin insecticide treatment did not differ significantly from that of the control. Even though there was no significant difference between 0.2ml lambda-cyhalothrin treatment and the control, there was still lower insect infestation of the plants treated with the 0.2ml insecticide compared to the control.

Increasing the concentration of lambda-cyhalothrin to 0.4ml, 0.6ml and 0.8ml as foliar spray followed a trend similar to using 0.2ml as foliar spray. Using 0.4ml lambda-cyhalothrin as foliar spray had two peaks of aphid infestation at week two and week six. Generally there were very small peaks at week two and bigger peaks at week six for all the three varieties when 0.4ml was used (Fig. 7). The 0.4ml treatment was effective in reducing the aphid population after the initial infestation of one week after germination to the fourth week.Then there was a rapid increase in the population of the aphid to week six. Using foliar spray at week six caused a rapid decline in infestation. The reasons for the decrease in aphid infestation when 0.2ml of lambda-cyhalothrin was used as a foliar spray might apply to 0.4ml.Further increase in the concentration of Lambda – cyhalothrin to 0.6ml as foliar spray on the three cowpea varieties showed a different trend of aphid infestations (fig 8). From one week after germination to the fifth week, the aphids' infestation levels were below a mean value of 1 for all the three cowpea varieties.

This is probably because increasing the concentration increases toxicity of the insecticide on the aphids. This implies that the incidence of insect pests attacking the cowpea was lowered to a manageable level by the application of the insecticides. According to (Liu et al., 2005) synthetic pyrethroids are among the commonly used pesticides for controlling agricultural and indoor pests. Interestingly, however, there was a sudden increase in the insect infestation at week five which peaked at week six. The high peak of insect infestation despite the increase in the insecticides concentration as well as the application of the foliar spray at the fourth week might be due to the rapid nature of their development. One week after the application of the foliar spray, aphids can develop rapidly within the second week before the next foliar spray application. This agrees with the findings of (Singh and Jackai, 1985) which stated that the adult aphid lives from 5 to 15 days and have a fecundity of over 100 with daily progeny production varying from 2 to 20.

When the foliar spray was applied at the 6th week, there was a decrease in the insect infestation. Again from the 7th week there was an increase in the infestation. The 0.8ml concentration of Lambda – cyhalothrin showed two peaks of aphid infestation. A lower peak occurred at week two and a higher peak was at week Six. These occurrences might be due to similar reasons as it is for the previous three Lambda- cyhalothrin concentrations.

The control plants rather demonstrated a very low level of aphid infestation from one week after germination to the fifth week. There was however a general sharp rise in aphid infestation from week five that peaked at week six for all the varieties. Nhyira cowpea variety recorded the highest level of aphids' infestations. There was a correspondingly sharp drop in the aphids' infestation for Nhyira variety from the sixth week to the seventh week. The aphid infestation rose again from week seven to week eight for Asetenapa. Nhyira levelled from week seven to week eight while Tona gently decreased from week seven to week eight (Fig. 9).

The very low level of aphid's infestations at one week after germination to the fifth week might be due to spray drift from the treated Plots to the control plots thereby reducing the aphids' infestation, even though precautionary measures were taken to prevent this occurrence.The continuous growth, development and maturation of the cowpea plants with particularly thicker vegetation made it impossible for the spray drift to continue to have any positive impact on the aphids hence the increase in infestation.

In this study, it was generally observed that there was a high aphid infestation on all the three cowpea varieties during the first two weeks after germination except the control. Environmental factors also play a vital role in the population build up for aphids. Planting of the cowpea varieties was carried out in the month of October which occurs within the minor rainy season. During this period, the amount of rainfall was low with mean rainfall of 106mm and temperatures ranged between $30.\ 3 - 32\ .0C^0$ (Appendices A and B) respectively.

Insect pests are known to develop and increase in numbers at moderate to high temperatures (Muthomi et *et al.*, 2008). The high temperatures might have caused a rapid increase in the aphid numbers resulting in the high aphid infestation. The incidence of insect infestation despite the use of the insecticide could be due to immunity of the insects to the insecticide. The insect pest could have developed the immunity by one or more of the following mechanisms. It could be due to delay in entry of the insecticide into the body, increased the detoxification of the insecticide or a decrease in sensitivity to the insecticide at its site of action. This finding agrees with the work of (Peter *et al.*, 1991) who observed that growing numbers of plant deceases, animal, insect and weeds are now immuned to pesticides.

Significantly higher grain yields were recorded in sprayed plots relative to the unsprayed plots. This implies that the incidence of insect pests attacking the cowpea was lowered to a manageable level by the application of the insecticide. The spraying resulted in effective control of the insect pests. This may have enabled the plants to manufacture and utilize assimilates to produce more biomass. Higher biomass yield is desirable for efficient utilization of water and nutrients. According to Olupot *et al.* (2004) this enables a crop to accumulate assimilates that are used for kernel development. The field of cowpea was hand weeded two weeks after germination. The absence of weeds implies less competition between the cowpea crop and weeds for space, sunlight, nutrient and water which are all essential for biomass development of the crop. This supports the work of Abulo *et al.* (2005) who reported that a high biomass yield also encourages efficient utilization of light and suppression of weeds. All these factors contribute to the final higher grain yield in the sprayed plots as compared to the control plots.

The improved yields observed for the 0.4 to 0.8 ml treatment range confirm earlier findings of Booker (1965) that the application of a number of insecticides have been shown to increase cowpea yields by several folds.

Sharma and Singh (2003) reported a significant decrease in pod damage with corresponding increase in grain yields after treating chickpea with dimethoate against *Heliotisarmigera.* Similarly, a mixture of karate and dimethoate EC at 400g ai/ha resulted in a reduction of pod and seed yield losses of up to 67 -71% respectively in Bambara groundnuts in Nigeria (Duke, 1997). In another work carried out in Kenya by Okeyo-Owuor and Kamala (1980) on pigeon pea found that seed yield losses due to insect infestation ranged between 25.8 and 62.7%.

The low yield obtained from the control plot on the other hand is obvious. This agrees with the findings of Peterson *et al.* (2004) who observed that there is a generalized primary physiological response to leaf mass consumption injury by insects among the cultivated legumes which affects the plants gas exchange variables such as photosynthetic, stomata conductance, intercellular CO_2 and respiration. Aphids' infestation on the cowpea crop causes darkening of the entire plant particularly the foliage. This reduces the photosynthetic activities which is quite essential for both vegetative and reproductive development of the plant.

Consequently, there was low grain yield obtained from the unsprayed plots as compared to the sprayed plots. This finding agrees with Mapose and Cossa (2005) who found that loss of foliage may result in yield reduction as it depresses the photosynthetic activity.

Considering the yields of the different varieties of cowpea used in the experiment against the different concentrations of the lambda-cyhalothrin insecticide used, the yield of Tona was higher (6.36kg/ha) against Asetenapa (6.17kg/ha) and Nhyira (5.01kg/ha) for 0.2ml insecticide concentration respectively. Nhyira cowpea variety at 0.2ml insecticide concentration yielded the lowest (4. 43kg/ha) whilst Tona variety yielded (6.94kg/ha) and Asetenapa variety gave the highest yield of (8.48kg/ha). At 0.6ml insecticide concentration, Tona variety yielded the highest (8.29kg/ha) followed by Asetenapa variety (7.33kg/ha) and the least being Nhyira variety (4.62kg/ha). This could be due to the yield potentials of the different varieties.

The yields for the three cowpea varieties at 0.8ml insecticide concentration had Nhyira variety with the least (6.36kg/ha) followed by Tona variety (6.94kg/ha) and Asetenapa variety (8.87kg/ha). However, total yields values for the three cowpea varieties are, 23, 69kg/ha, 32.85kg/ha and 34.99kg/ha for Nhyira, Tona and Asetenapa respectively. This gave Asetenapa the highest grain yield value. These yield values are relatively lower. The low yield could be attributed to probably the fact that other fungal and viral diseases were not attended to. Cowpea crop is vulnerable to many other pests and disease if not treated can cause low grain yields. This work is in contrast with the findings of Adu-Dappah *et al.*(2006) who reported that these cowpea varieties,Tona, Nhyira and Asetenapa are resistant and tolerant to most of cowpea viral diseases such as cercospora leaf spot and anthracnose,a mere suspicion.They also have higher yields potential than the finding of this study.

On the average, Asetenapa variety yielded the highest (34.99kg/ha) followed by Tona variety (32.85kg/ha) and finally Nhyira (23.69kg/ha). This is in contrast with the finding of Adu-

Dapaah et al , (2006) who reported the yield potentials of these cowpea varieties to be, Tona (1679-2390kg/ha), Nhyira (1058-2460kg/ha) and Asetenapa (976- 1322kg/ha). Since yields are the ultimate data for comparison, the results suggest that any of the insecticide concentrations could be used in the control of *Aphis craccivora* insect pest in the cowpea production except the control. Although 0.8ml insecticide concentration had higher yield, it did not differ from the other treatments statistically. The study showed that the use of lambda-cyhalothrin super was useful for the management of the common insect pest in legumes. However, to avoid development of insect resistance as reported by Ekesi (1999), it is imperative to establish optimum spray-program timing.

CHAPTER SIX

CONCLUSION AND RECOMMENDATIONS

6.1 CONCLUSION

Treatment two (0.2ml) was the minimum effective dose followed by treatment three (0.6 ml) with treatment four (0.8ml) being the most efficacious dosage of lambda-cyhalothrin for the control of *Aphis craccivora* on the three varieties (*Tona, Asetenepa* and *Nhyira*) studied. Disappointingly, however, even though there were some differences across treatments within the test varieties obtained, those differences were not significant. *Asetenapa* (0.89 t/ha) was the highest yielding variety followed by *Nhyira* (0.69 t/ha) with *Tona* (0.64 t/ha) being the lowest yielding variety for treatment four (for the most efficacious 0.8 ml treatment).

6.2 RECOMMENDATIONS

It is recommended that:

1. Further work involving a wider spacing between the dosages of lambda-cyhalothrin applied is suggested to confirm or disprove the results obtained in this study.
2. Further study could be carried out to verify if immunity to lambda-cyhalothrin does develop that quickly in cowpea crop.
3. Insecticides application could begin about two weeks after germination as this research work has revealed that aphid infestation occurs mostly in the second week after germination.
4. Ideally, the author sides with the succeeding statement advocating for monitored rather than calendar-based insecticide application.This could be adopted in the Ghanaian cowpea pest control program. This will go a long way to reduce the cost of production and above all lessen the general environmental effect of insecticides.
5. For obvious environmental reasons, integrated pest management (IPM) should be encouraged with chemical insecticide being a last resort.
6. Further investigation could be conducted during the major season for comparison with the minor season's results.

7. Also, further studies on alternative non-chemical management strategies are recommended to avoid accumulation of residues in the environment and Human foods.

REFERENCES

Abate, T., Huis, A.V., and Ampofo, J.K.O. (2000) Pest Management Strategies in Traditional Agriculture: An African Perspective, *Annu. Rev. Entomol*. 45:631–659.

Abulo, P., G. Olupot, V.A. Ochwoh and E. Adipala, (2005). Effect of phosphate fertilizer application on the yirld of groundnuts in Central Uganda. Afr. Crop Sci. Conf. Proc., 7:37-40.

Adu-Dapaah, H.K., Asibuo J.Y., Asafo-Adjei, B., Amoah, S., Asumadu, H., Osei-Bonsu, P., Osei-Yeboah, S.Y., Danquah, O.A., Owusu-Akyaw, M., Lamptey, J.N., Anchirinah, V., Haleegoah, J., Asiedu, E.A., Annan, N., Agyeman, A., Osei-Hyeamang, N., Acquah, M., Addo, J.K., Asafu-Agyei, J.N. (2006). Breeding Methodology, Botanical and Agronomic Characteristics of Two Cowpea Genotypes being proposed for release. Plant Breeding Unit, Council for Scientific and Industrial Research (CSIR), Kumasi.

Ajeigbe, H.A. and Singh, B.B. (2006) Integrated pest management in cowpea: Effect of time and frequencyof insecticide application on productivity, *Crop Protection, 25, 920–925.*

Amatobi, C. I. (1994). Field Evaluation of some insecticides for the control of insect pests of cowpea (*Vignaunguiculata* (L.) Walp.) In the Sudan Savanna of Nigeria, *International Journal of Pest Management*, 40 (1) 13- 17.

Ambang, Z., Ndongo, B., Amayana, D., Djile, B., Ngoh, J.P., Chewachong, G.M. (2009) combined effect of host plant resistance and insecticides application on the development of cowpea viral diseases. Australian Journal of Crop Science, 3(3):167-172.

Ampomah O.Y., Ofori-Ayeh E., Solheim B., Svenning M.M. (2008). Host range, symbiotic effectiveness and nodulation competitiveness of some indigenous cowpea bradyrhizobiaisolates from the transitional savanna zone of Ghana, *African Journal of Biotechnology* Vol. 7 (8), 988-996.

Anonymous. (2003). Data base on pesticides and the environment. Economic and Social Commission for Asia and the Pacific (ESCAP), Centre de cooperation

Internationale en RechercheAgronomique Pour le Development (CIRAD), Commisiton of the European Union (E.U). http://www.fadnap.com/pesticede. Last accessed: 30th January, 2009.

Anonymous. (2007) Environmental Health Fact sheet. Pyrethorid insecticide. (http://www.idph.state.il.ils/envheathl/wnv.htm). Last accessed: 21st March, 2009.

Bashir, M. and Hampton, R.O. (1996) Detection and identification of seed- borne viruses from cowpea (*Vignaunguiculata* (L.) Walp) germplasm. *Plant Pathology.* 45, 54 -58.

Bashir, M., Ahmad, Z. and Ghafoor, A. (2002). Cowpea aphid-borne mosaic potyvirus: a review; *International Journal of Pest Management*, 48 (2) 155-168.

Blackman R.L.andEastop V.F. (2000) Aphids on the World's Crops: An Identification and Information Guide, 2nd Edn. Wiley, Chichester, UK, 1- 466.

Booker, R.H. (1965). Pests of cowpea and their control in northern Nigeria.*Bulletin of Entomological Research,* 55, 663-6772.

Bressani, R. (1985). Nutritive value of Cowpea. In: Cowpea Research, Production and Utilization. S.R Singh and K. O. Rachie (eds.), JohnWiley&Sons Ltd, pp. 353- 359.

Capinera, J. L. (2008). Encyclopaedia of Entomology, 2nd Edition, Volume 4 (S-Z), Springer Science + Business Media B.V., 1-4346.

Cowpea Production Guide (1990) Leaflet from the Information Support Unit/ Agricultural Extension Services Department, Ministry of Food and Agriculture (MOFA). 9pp.

Dakora, F. D., Chimphango, S. B. M., Gepts, P. L., Lazaro, E., Loubser, H., Naab, J. B., Phillips, D. A., Sibuga, P. K. and Tanzubil, P. B. (2004). Using Plant Flavonoids as heritable traits to increase symbiotic nitrogen fixation, yields and pest resistance of indigenous African Legumes, Progress Report for Year 1, The Mcknight Foundation Command and Control Research Program CCRP (1-90).

Dike, M.C., (1997).Effect of insect pests on pod and seed yields of bambara groundnut, vignasubterreaneaL.Vrede in Nigeria. Int. J.Pest Manage.,43:191-192.

Dugje, I. Y., Ekeleme, F., Kamara, A. Y., Omoigui, L. O., Tegbaru, A., Teli, I. A. and Onyibe, J. E. (2008). Guide to safe and effective use of pesticides for crop production in Borno State, Nigeria. 1-30.

Edwardson, J.R. and Christie, R.G. (1991) CRC Handbook of Viruses Infecting Legumes. CRC Press, Inc., 2000 Corporate Blvd., N.W., Boca Raton, Florida. USA. 1-540.

Ehlers, J. D. and Hall, A. E. (1997), Cowpea (*Vignaunguiculata* L. Walp), *Field CropsResearch* 53, 187-204.

Ekesi, S., (1999).Insecticide resistance in field populations of the legumepod- borer, *Marucavitrata Fabircius* (*Lepidoptera: Pyraiidae*), on cowpea, *vigna unguiculata*(L.), Walp in Nigeria.Int. J.Pest Manage., 45: 57-59.

Ennin, S.A., Dapaah, H.K. and Abaidoo, R.C. (2004). Nitrogen Credits from Cowpea, Soybean, Groundnut and Mucuna to Maize in Rotation, *West African Journal of Applied Ecology*, Vol. 6.

Ennin-Kwabiah, S. and Osei-Bonsu, P. (1993) Management of cowpea, soybean and groundnut in tropical cropping systems. CRI Crop Management Research Training. Crop Management Guide 36. pp. 34.

Environmental Audit and Institutional Strengthening in Wenchi District. (1996). Bureau of Integrated Rural Development (BIRD) University of Science and Technology (UST), Kumasi.

Etsey, A.N., Sakyi-Dawson, E., Sefa-Dedeh, S., OheneAfoakwa, E., Tano-Debrah, K. and Annor, G.A. (2007) Effects of cowpea fortification and the level of ripeness of plantain on the nutritive value of plantain based snack foods, *African Journal of Biotechnology* Vol. 6 (6), 799-802.

Fatokun, C.A., Tarawali, S.A., Singh, B.B., Kormawa, P.M. and Tamò, M. (2002). Challenges and Opportunities for Enhancing Sustainable Cowpea Production. Proceedings of the World Cowpea Conference III held at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 4–8 September 2000. IITA, Ibadan, Nigeria.

Ghana/CIDA Grains Development Project (1991). Maize and Cowpea Production Guide. pp. 16.

Girousse, C., Moulia, B., Silk, W. &Bonnemain, J. L. (2005) Aphid infestation causes different changes in carbon and nitrogen allocation in alfalfa stems as well as different inhibitions of longitudinal and radial expansion. *Plant Physiol.* 137: 1474-1484.

Gudrups, A. E. and Bruce, P. (1997). The storage and marketing of pulses in Ghana. *NRI Report*, No. 32. pp 31.

Hampton, R.D., S.E. Albrechtsen, and S.B. Mathur. 1992. Seed Health (Viruses) of vignaunguiculata selection from developing countries. Seed Science and Technology 20: 23 -38.

Hampton, R.O., Thottappilly, G., and Rossel, H.W. (1997). Viral diseases of cowpea and their control by resistance-conferring genes. In: Singh, B.B., Mohan Raj, D.R., Dashiell, K.E., and Jackai, L.E.N. (Eds). Advances in Cowpea Research. Copublication of Interntional Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria. 159-175.

Hueguenot, C., Furneaux, M.T.and Hamilton, R.I. (1994). Capsid protein properties of cowpea aphid borne mosaic virus and black eye cowpea mosaic virus confirm the existence of two major subgroups of aphid transmitted, legume-infecting potyviruses. *Journal of General Virology*75: 3555 – 3560.

IITA(2006) – Details of Production Levels for Cowpea. Available at: http://www.iita.org/cms/details/cowpea_project_details.aspx?zoneid=63&articleid=269 visited on: 25th October, 2008.

Isman, M.B. (2006). Botanical Insecticides, Deterrents, and Repellents in Modern Agriculture and an Increasingly Regulated World; *Annu. Rev. Entomol.*, **51**:45–66.

Jackai L.E.N. and Adalla, C. B. (1997). Pest management practices in cowpea: a review. In: Singh, B. B., D. R. Mohan Raj, K. E. Dashiell and L.E.N.Jackai (Eds).1997. Advances in Cowpea Research. Co publication of International Institute of Tropical Agriculture

(IITA) and Japan Research Centre for Agriculture Sciences (JIRCAS). IITA, Ibadan, Nigeria, pp.240-258.

Jackai, L.E.N. and Daoust R.A. (1986) Insect Pests of Cowpea. *Ann. Rev. Entomol*. 31: 95-119.

Kareem, K.T. and Taiwo M.A. (2007) Interactions of Viruses in Cowpea: effects on growth and yield parameters. *Virol J.* 7; 4: 15.

Karungi, J., Adipala, E., Ogenga-Latigo, M.W., Kyamanywa, S. and Oyobo, N. (2000a) Pest management in cowpea. Part 1. Influence of planting time and plant density on cowpea field pests infestation in eastern Uganda; *Crop Protection* 19, 231-236.

Karungi, J., Adipala, E., Ogenga-Latigo, M .W.Kyamanywa, S. and Oyobo, N. (2000b). Pest management in cowpea. Part 2. Integrating planting time, plant density and insecticide application for management of cowpea field insect pests in eastern Uganda; *Crop Protection*19, 237-245.

Kay, D.E. (1979). Crop and Product Digest. No.3. Food Legumes. London; Tropical Product Institute, xvix 435pp.

Langyintuo A.S., Lowenberg-DeBoer J., Faye M., Lambert D., Ibrod D., Moussad B., Kergnae A., Kushwahaf S., Musaf S. and Ntoukam G. (2003) Cowpea supply and demand in West and Central Africa, *Field Crops Research* 82 , 215–231.

Lauffer, M.A. and Maramorosch, K. (1983) Advances in Virus Research, Volume 28, 1 – 478.

Leahey, J.P (1985). Metabolism and Environmental Degradation and the Pyrethroid insecticides Ed. By Leahey J.P., Taylor and Francis.

Liu, W. P., Gan, T. Y., Schlenk, D., and Jury, W. A. (2005). Enantioselectivity in environmental safety of current chiral insecticides. *Proc. Nat. Acad. Sci.* U.S.A 102. 701 -706.

Mapose, I.C. andL.S.Cossa, 2005. Yield and quality responses of cowpea varieties to partial defoliations as vegetable. Afr.Crop Sci. Conf. Proc., 7: 41-43.

Map of Ghana showing the location of Wenchi.

http://www2.truman.edu/~mseipel/ghana.html Last accessed: 3rd April, 2011.

Monti, L. M., Murdock, L. L and Thottapply, G. (1997). Opportunities for biotechnology in cowpea: In: Singh, B. B., D.R.Mohan Raj, K. E. Dashiell and L. E. N. Jackai (Eds). 1997. Advancces in cowpea Research, Co publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria. pp. 341-351.

Mugo,H.M.,(1989).Studies of insect pests of pigeon pea (*Cajanuscajan Mill sp.*) during the flowering and post flowering stage and their impact on seed yield in Kenya. M.Sc.Thesis, University of Nairobi, Kenya.

Muthomi, J.W., Otieno, P.E., Chemininingwa, G.N.Nderitu, J.H and.Wagacha, J.M (2008). Effects of Chemical spray on insect pestand yield quality of food grain legumes. J. Entomol., 5:156-163.

Ofuya T.I and Okuku I. E. (1994) Insecticidal effect of some plant extracts on the cowpea aphid *Aphis craccivora* Koch (Homoptera: Aphididae), Anz. Sch/idlingskde., Pflanzenschutz, Umweltschutz 67, 127-129.

Ofuya, T.I. (1997). Control of the cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae), in cowpea, *Vignaunguiculata* (L.) Walp. *Integrated Pest Management Reviews* **2,** 199-207.

Ogbuinya, P.D. (1997)." Advances in cowpea research". Biotechnology and Development Monitor No. 33: 10-12.

Okeyo-Owuor, J.B.and C.P.M. Kamala, (1980). Insect pod borers of pigeon pea (*CajanusCajan* (L.)Mill sp) and their influence on developing pods and final seed yield in KenyaJ.Sci. Technol., 1: 79-86.

Olupot, G., Etiang, J., Ssali, H. and Nahasirye, M., (2004). Sorgum yield response to kraal manure combined with mineral fertilizers in Eastrn Uganda. MUARIK Bull., 7:30-37.

Padulosi, S and Ng, N. Q. (1997). Origin, taxonomy and morphology of Vignaunguiculata (L) Walp. In: Singh, B.B., D. R. Mohan Raj, K.F. Dashiell and L.E.N. Jackai (Eds).

(1997). Advances in cowpea Research, Co publication of International Institute of tropical Agriculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria, pp 1 – 12.

Pegadaraju, V, Knepper, C., Reese, J.and Shah, J. (2005). Premature leaf senescence modulated by the Arabidopsis phytoalexin deficient 4 gene is associated with defense against the phloem-feeding green peach aphid. *Plant Physiol*. 139:1927-1934.

Perring, T. M., Gruenhagen, N. M. and Farrar, C. A. (1999). Management of Plant Viral Diseases through chemical control of insect vectors. *Annu. Rev. Entomol*. 44:457–81.

Peter, H., Alastair, H. and Nigel, D. (1991). The pesticide Hand book by Journeyman Press, 345 Archway Road, London N65AA and 141 Old Bedford Road, Concord MA01742, USA. 358 pp.

Peterson, R.K.D., C.L. Shannon and A.W. Lenssen, (2004). Photosynthetic responses of legume species to leaf-mass consumption injury. Environ. Entomol, 33:450-456.

Phillips, R.D., McWatters, K.H., Chinnan, M.S., Hung, Y.C., Beucha,t L.R., Sefa-Dedeh, S., Sakyi-Dawson, E., Ngoddy, P., Nnanyelugo, D., Enwere, J., Komey, N.S., Liu, K., Mensa-Wilmot, Y., Nnanna, I.A., Okeke, C., Prinyawiwatkul, W., Saalia, F.K. (2003) Utilization of cowpeas for human food, *Field Crops Research* 82, 193–213.

Phillips, R.D. and McWatters, K.H. (1991). Contribution of Cowpeas to Nutrition and Health. *Food Technol. 45(9):127-130.*

Powell, G. and Hardie, J. (2006). Xylem ingestion by winged aphids. *Entomologia Experimentalis ET Applicata*104: 103–108.

Pradhan, S. (1992). Insect Pests of Crops. The Director, National Book Trust, India. A-S, Green Park, New Delhi-110016. 200pp.

Raheja, A.K. and Leleji, O. I. (1974) an aphid – borne virus disease of irrigated cowpea in Northern Nigeria. *Plant Disease Reporter,* 58:1080-1084.

Rao, M.R., Singh, M.Pand Day, R. (2000). Insect pest problems in tropical agro forestry systems; Contributory factors and strategies for management. Agro.For.Syst, 50: 243-277.

Sharma, J.P. and Singh, K. (2003). Efficacy and economics of certain insecticides in the management of pod borer in chockpea. Indian J. Pulses Res., 16(2): 167-168.

Singh, B. B., Mohan Raj, D.R., Dashieu, K. E. and Jackai, L. E. N. (1997). In: Advances in Cowpea Research. Co- publication of International Institute of Tropical Agriculture (IITA) and Japan International Research Center for Agriculture Sciences (JIRCAS) IITA, Ibadan, Nigeria. 375pp.

Singh, S.R., Jackai, J.E.N, Santos, J.H.R and Adalla, C, B. (1990).Insect pests of cowpea. In: Insect pests of tropical food legumes, edited by Singh, S.R(Ed). John Wiley and sons, Chickster, U.K, pp. 43-89.

Singh, S. R. (1985). Insects Damaging Cowpea in Asia. Cowpea Research, Production and Utilization. In S. R. Singh and K. O Rachie (Ed). Chichester: John Wiley and Sons. pp 247-64.

Singh, S. R. and Jackai, L. E. N. (1985). Insect pests of cowpea in Africa. Their life cycle, economic emportance, and potential for control. In S. R. Singh and K. O Rachies (Eds) Cowpea Research, Production and Utilization. Pp 217-31. Chichester: John Wiley and Sons.

Singh, S.R. and Rachie, K.O. (Eds) (1985). Cowpea Research, Production and Utilization. Chichester: John Wiley and Sons.pp.106-15.

Shoyinka, S. A. (1974) Status of virus diseases of cowpea in Nigeria (1974) In Proceedings of the First IITA grain Legumes Improvement Workshop IITA, Ibadan, Nigeria. 270-273.

Shoyinka, S.A., Thottappilly, G., Adebayo, G.G. and Anno-Nyako, F.O. 1997. Survey on Cowpea virus incidence and distribution in Nigeria. *International Journal of Pest Management* 43:127-132.

Stiling, P.D. (1985) an introduction to insect-pest and their control. Macmillan Publishers Ltd. 93pp.

Taiwo, M.A., Kareem, K.T., Nsa, I.Y. and Hughes, J.D.A. (2007). Cowpea viruses: Effect of single and mixed infections on symptomatology and virus concentration, *Virology Journal*, **4**:95.

Tewary, D. K., Bhardwaj, A. and Shanker, A. (2005). Pesticidal activities in five medicinal plants collected from hills of western Himalayas, *Industrial Crops and Products 22*, 241–247.

Thottapilly, G. and Rossell, H.W. 1985. World wide occurrence and distribution of virus diseases. In. S.R. Singh and K.O. Rachie (Eds) cowpea Research, production and utilization pp. 155-71 Chichester: John Wiley and sons.

Tindall, H.D. (1992). Food Legumes. Published by the Macmillan Press Ltd, London and Basingstoke. 103 pp.

Tokunaga, E. and Suzuki, N. (2008) Colony growth and dispersal in the ant-tended aphid, *Aphis craccivora* Koch, and the non-ant-tended aphid, *Acyrthosiphonpisum* Harris, under the absence of predators and ants, *PopulEcol*, 50:45–52.

Van Emden, H.F. and Harrington, R. (2007) Aphids as Crop Pests. CAB International.

Verghese, A. and Jayanthi, P.D.K (2002) a technique for quick estimation of aphid numbers in field, *Current Science*, Vol. 82, No. 9.

Wellings, P. W., Ward, S. A., Dixon, A. F. G., andRabbinge, R. (1989). Crop loss assessment. In: Minks AK, Harrewijn P, (editors). Aphids, theirbiology, natural enemies and control. Volume C. Amsterdam: Elsevier. pp 49–64.

William, G.R. and Marcos, K. (1994). The Quantitative basis of pest management: Sampling and Measuring. In: Robert, L M. and William, H.L. (Eds). Introduction to insect pest management, A Wiley- InterscciencePublication.

Whitworth, R.J. and Ahmad, A. (2009). Cowpea aphid Kansaa State University Agricultural Experiment Station and Cooperative Extension Service.

APPENDICES

APPENDIX: A RAINFALL DATA FROM PLANTING TO HARVESTING

(I.E. OCTOBER, NOVEMBER AND DECEMBER 2008)

OCTOBER	
DATE	**AMOUNT (mm)**
1/10/08	10.1
3/10/08	15.1
6/10/08	29.4
10/10/08	94.0
11/10/08	16.9
12/10/08	6.4
13/10/08	15.9
15/10/08	27.4
16/10/08	15.9
17/10/08	5.3
18/10/08	11.6
19/10/08	7.4
22/10/08	4.8
25/10/08	0.6
27/10/08	4.8
29/10/08	14.9
30/10/08	12.6
Total	**280.00**
NOVEMBER	
DATE	**AMOUNT (mm)**
5/11/08	0.2
9/11/08	0.1
10/11/08	4.1
11/11/08	6.2
20/11/08	16.9
21/11/08	3.8
25/11/08	7.1
Total	**38.4**
DECEMBER	
DATE	**AMOUNT (mm)**
	Nil

Source: **Wenchi Meteorological Station (2008)**

APPENDIX B: MEAN MAXIMUM TEMPERATURE VALUES FOR OCTOBER, NOVEMBER AND DECEMBER 2008

MONTH	MEAN TEMPERATURES(°C)
OCTOBER	30.3
NOVEMBER	31.1
DECEMBER	32.0

SOURCE: Wenchi Meteorological Station

APPENDIX C: EFFECT OF TREATMENTS ON VARIETAL APHID INFESTATION LEVELS – MEAN VALUES FOR GRAPH

	Lambda-cyhalothrin Treatments				Control
Varieties	0.2 ml	0.4 ml	0.6 ml	0.8 ml	NT
Tona	23	11.67	7.67	6.67	31.67
Asetenapa	11	8	11.33	3.67	32.33
Nhyira	6.67	3.33	4.33	3.33	18.00

- Numbers represent the means of three replications.

STANDARD ERRORS

T1	T2	T3	T4	T5
6.2450	6.0090	1.2020	2.4040	7.5350
A1	A2	A3	A4	A5
2.8870	3.1800	4.0960	0.8820	4.1770
N1	N2	N3	N4	N5
3.1800	0.6670	0.8820	1.3330	5.8590

APPENDIX D: DESCRIPTIVE STATISTICS – TONA YIELD FOR TREATMENTS

Descriptive Statistics: Tuesday, December 22, 2009, 09:45:16

Data source: TONA in Tona

Column	Size	Missing	Mean	StdDev	Std. Error	C.I. of Mean
0.2	3	0	550.000	229.129	132.288	569.187
0.4	3	0	600.000	180.278	104.083	447.834
0.6	3	0	716.667	301.386	174.005	748.684
0.8	3	0	600.000	180.278	104.083	447.834
NT	3	0	375.000	108.972	62.915	270.703

Column	Range	Max	Min	Median	25%	75%
0.2	450.000	750.000	300.000	600.000	375.000	712.500
0.4	350.000	750.000	400.000	650.000	462.500	725.000
0.6	600.000	1000.000	400.000	750.000	487.500	937.500
0.8	350.000	750.000	400.000	650.000	462.500	725.000
NT	200.000	450.000	250.000	425.000	293.750	443.750

Column	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilkProb
0.2	-0.935	--	0.253	0.487	0.964	0.637
0.4	-1.152	--	0.276	0.404	0.942	0.537
0.6	-0.492	--	0.211	0.610	0.991	0.817
0.8	-1.152	--	0.276	0.404	0.942	0.537
NT	-1.630	--	0.343	0.179	0.842	0.220

APPENDIX E: ANOVA OF TONA YIELD FOR TREATMENTS

One Way Repeated Measures Analysis of Variance

Monday, December 21, 2009, 19:43:56 **Data source:** Data 1 in Notebook3

Normality Test: Passed (P = 0.285) **Equal Variance Test:** Failed (P < 0.050)

Treatment Name	N	Missing	Mean	StdDev	SEM
0.2	3	0	550.000	229.129	132.288
0.4	3	0	600.000	180.278	104.083
0.6	3	0	716.667	301.386	174.005
0.8	3	0	600.000	180.278	104.083
NT	3	0	375.000	108.972	62.915

Source of Variation	DF	SS	MS	F	P
Between Subjects	2	390583.333	195291.667		
Between Treatments	4	185166.667	46291.667	7.431	0.008
Residual	8	49833.333	6229.167		
Total	14	625583.333			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.008). To isolate the group or groups that differ from the others use a multiple comparison procedure.

Power of performed test with alpha = 0.050: 0.876

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05

Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant
0.6 vs. NT	341.667	5.302	<0.001	0.005	Yes
0.8 vs. NT	225.000	3.492	0.008	0.006	No
0.4 vs. NT	225.000	3.492	0.008	0.006	No
0.2 vs. NT	175.000	2.716	0.026	0.007	No
0.6 vs. 0.2	166.667	2.586	0.032	0.009	No
0.6 vs. 0.4	116.667	1.810	0.108	0.010	No
0.6 vs. 0.8	116.667	1.810	0.108	0.013	No
0.4 vs. 0.2	50.000	0.776	0.460	0.017	No
0.8 vs. 0.2	50.000	0.776	0.460	0.025	No
0.4 vs. 0.8	0.000	0.000	1.000	0.050	No

APPENDIX F DESCRIPTIVE STATISTICS – ASETENAPA YIELD

FORTREATMENTS

Descriptive Statistics: Tuesday, December 22, 2009, 10:05:07

Data source: ASETENAPA in Asetenapa

Column	Size	Missing	Mean	StdDev	Std. Error	C.I. of Mean
0.2	3	0	533.333	160.728	92.796	399.269
0.4	3	0	733.333	125.831	72.648	312.580
0.6	3	0	633.333	275.379	158.990	684.078
0.8	3	0	766.667	189.297	109.291	470.240
NT	3	0	358.333	166.458	96.105	413.505

Column	Range	Max	Min	Median	25%	75%
0.2	300.000	650.000	350.000	600.000	412.500	637.500
0.4	250.000	850.000	600.000	750.000	637.500	825.000
0.6	550.000	900.000	350.000	650.000	425.000	837.500
0.8	350.000	900.000	550.000	850.000	625.000	887.500
NT	325.000	500.000	175.000	400.000	231.250	475.000

Column	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilkProb
0.2	-1.545	--	0.328	0.225	0.871	0.298
0.4	-0.586	--	0.219	0.590	0.987	0.780
0.6	-0.271	--	0.191	0.643	0.997	0.900
0.8	-1.597	--	0.337	0.197	0.855	0.253
NT	-1.056	--	0.265	0.442	0.953	0.583

APPENDIX G: ANOVA OF ASETENAPA YIELD FOR TREATMENTS

One Way Repeated Measures Analysis of Variance

Monday, December 21, 2009, 19:39:47 **Data source:** ASETENAPA in Notebook2

Normality Test: Passed (P = 0.361)

Equal Variance Test: Passed (P = 0.799)

Treatment Name	N	Missing	Mean	StdDev	SEM
0.2	3	0	533.333	160.728	92.796
0.4	3	0	733.333	125.831	72.648
0.6	3	0	633.333	275.379	158.990
0.8	3	0	766.667	189.297	109.291
NT	3	0	358.333	166.458	96.105

Source of Variation	DF	SS	MS	F	P
Between Subjects	2	302250.000	151125.000		
Between Treatments	4	328166.667	82041.667	10.969	0.002
Residual	8	59833.333	7479.167		
Total	14	690250.000			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.002). To isolate the group or groups that differ from the others use a multiple comparison procedure.

Power of performed test with alpha = 0.050: 0.977

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05

Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant
0.8 vs. NT	408.333	5.783	<0.001	0.005	Yes
0.4 vs. NT	375.000	5.311	<0.001	0.006	Yes
0.6 vs. NT	275.000	3.895	0.005	0.006	Yes
0.8 vs. 0.2	233.333	3.304	0.011	0.007	No
0.4 vs. 0.2	200.000	2.832	0.022	0.009	No
0.2 vs. NT	175.000	2.478	0.038	0.010	No
0.8 vs. 0.6	133.333	1.888	0.096	0.013	No
0.4 vs. 0.6	100.000	1.416	0.194	0.017	No
0.6 vs. 0.2	100.000	1.416	0.194	0.025	No
0.8 vs. 0.4	33.333	0.472	0.649	0.050	No

APPENDIX H DESCRIPTIVE STATISTICS – NHYIRA YIELD FOR TREATMENTS

Descriptive Statistics: Tuesday, December 22, 2009, 10:15:55

Data source: NHYIRAA in Nhyira

Column	Size	Missing	Mean	StdDev	Std. Error	C.I. of Mean
0.2	3	0	433.333	104.083	60.093	258.557
0.4	3	0	383.333	28.868	16.667	71.711
0.6	3	0	400.000	180.278	104.083	447.834
0.8	3	0	550.000	50.000	28.868	124.207
NT	3	0	283.333	76.376	44.096	189.729

Column	Range	Max	Min	Median	25%	75%
0.2	200.000	550.000	350.000	400.000	362.500	512.500
0.4	50.000	400.000	350.000	400.000	362.500	400.000
0.6	350.000	600.000	250.000	350.000	275.000	537.500
0.8	100.000	600.000	500.000	550.000	512.500	587.500
NT	150.000	350.000	200.000	300.000	225.000	337.500

Column	Skewness	Kurtosis	K-S Dist.	K-S Prob.	SWilk W	SWilkProb
0.2	1.293	--	0.292	0.344	0.923	0.463
0.4	-1.732	--	0.385	0.089	0.750	<0.001
0.6	1.152	--	0.276	0.404	0.942	0.537
0.8	0.000	--	0.175	0.654	1.000	1.000
NT	-0.935	--	0.253	0.487	0.964	0.637

APPENDIX I ANOVA OF NHYIRA YIELD FOR TREATMENTS

One Way Repeated Measures Analysis of Variance

Normality Test: Passed (P = 0.808) **Equal Variance Test:** Passed (P = 0.588)

Treatment Name	N	Missing	Mean	StdDev	SEM
0.2	3	0	433.333	104.083	60.093
0.4	3	0	383.333	28.868	16.667
0.6	3	0	400.000	180.278	104.083
0.8	3	0	550.000	50.000	28.868
NT	3	0	283.333	76.376	44.096

Source of Variation	DF	SS	MS	F	P
Between Subjects	2	63000.000	31500.000		
Between Treatments	4	111000.000	27750.000	5.286	0.022
Residual	8	42000.000	5250.000		
Total	14	216000.000			

The differences in the mean values among the treatment groups are greater than would be expected by chance; there is a statistically significant difference (P = 0.022). To isolate the group or groups that differ from the others use a multiple comparison procedure.

Power of performed test with alpha = 0.050: 0.70

All Pairwise Multiple Comparison Procedures (Holm-Sidak method):

Overall significance level = 0.05 Comparisons for factor:

Comparison	Diff of Means	t	Unadjusted P	Critical Level	Significant?
0.8 vs. NT	266.667	4.507	0.002	0.005	Yes
0.8 vs. 0.4	166.667	2.817	0.023	0.006	No
0.2 vs. NT	150.000	2.535	0.035	0.006	No
0.8 vs. 0.6	150.000	2.535	0.035	0.007	No
0.8 vs. 0.2	116.667	1.972	0.084	0.009	No
0.6 vs. NT	116.667	1.972	0.084	0.010	No
0.4 vs. NT	100.000	1.690	0.129	0.013	No
0.2 vs. 0.4	50.000	0.845	0.423	0.017	No
0.2 vs. 0.6	33.333	0.563	0.589	0.025	No
0.6 vs. 0.4	16.667	0.282	0.785	0.050	No