INSECT FAUNA OF UPLAND RICE IN THE KWAEBIBIREM DISTRICT OF THE EASTERN REGION OF GHANA

By

Ayitey Armah
(B. Sc. (Hons.) Dip. Ed. (UCC)

A thesis presented in partial fulfillment of the requirements for the degree of M.Phil, Entomology of University of Ghana

Insect Science Programme*
University of Ghana, Legon

October 2001

*** Joint interfaculty international programme for the training of entomologists in West Africa. Collaborating Departments: Zoology (Faculty of Science) and Crop Science (Faculty of Agriculture)**

DECLARATION

I do hereby declare that the experimental work described in this thesis was carried out by me and that all cited references have been duly acknowledged. This thesis either in whole or in part has not been submitted for any other degree in any institution or organization elsewhere.

CANDIDATE ....

AYITEY ARMAH

SUPERVISOR ....

M. A. COBBLAH (MISS)

SUPERVISOR ....

DR. OBENG-OFORI

SUPERVISOR ....

PROF. K. AFREH-NUAMAH

DEDICATION

Aryee

Deidei

Korkoi and

Joyce

for time taken away from them.

ACKNOWLEDGEMENT

I acknowledge the contribution by Prof. K. Afreh-Nuamah of the University of Ghana Agricultural Research Station (ARS), Kade for proposing and supervising this work. I am grateful to M. A. Cobblah (Miss), Department of Zoology, University of Ghana for assistance in identifying the insects as well as in directing and preparation of the thesis. I also acknowledge the interest of Dr. Ofosu-Budu of University of Ghana, ARS Kade, Dr. Obeng-Ofori of the Crop Science Department, University of Ghana and Mr. Anthony Ofosu, formerly of the Crop Research Institute-Pokuase for assistance during the preparation of this thesis. I thank Prof. J. N. Ayertey, Dean of Graduate Studies, University of Ghana and Coordinator, Africa Regional Postgraduate Programme in Insect Science for providing financial assistance.

I appreciate the use of computer facilities made available by the Green Earth Organization (GEO). Finally, I thank Mrs. Sarah D. Abassah of Green Earth Organization for typing this work.

TABLE OF CONTENTS

ABSTRACT

A survey was carried out in the Kwaebibirem District of the Eastern Region of Ghana to identify insect pests and natural enemies of upland rice both in the field and storage. The study lasted from September 1999 to October 2000.

Field insects were sampled from five communities in the district i.e. Agricultural Research Station (ARS)-Okumaning, Subi, Abodom, Abaam and Prankese. Two line transects twenty five meters apart were fixed through each rice field. On the first line transect, insects were collected by walking and sweeping with net. On the second line transect, ten hills were marked. The tillers of marked hills were examined visually. Insects found on the tillers at different crop growth stages were determined, identified and counted on each sampling period.

In storage, tied bundles of paddy of 100 panicles each were stacked into heaps and stored in a wooden ban at an initial moisture content of 15%. Sticky and crevice traps were used to monitor insect activity. Two bundles each of tied paddy were selected, from the top layer, middle layer and bottom layer, placed in plastic bags and frozen for 12 hours to kill insects. These bundles of paddy were untied and mummified insect bodies were identified and counted. Students t test (P = 0.05) was used to test for significance.

Twelve insect pest species from nine families were identified from the field studies. Of these *Diopsis thoracica* (Diptera: Diopsidae) represent 65%, *Conocephalus longipennis, Taphronota* sp., *Turbida* sp., *Acrida* sp., *Catoptropteryx* sp., *Zonocerus variegates* (Orthoptera) 25% and *Aspavia* sp., *Nezara* sp., *Oebalus* sp. (Pentatomidae) 10% of the total number of insect pests sampled.

Spiders (unidentified) formed 75% of the number of natural enemies. Odonata (*Palplopluera lucia, Orthetrum stemmate, Enallagma* sp., *Agriocnemis* sp.)

formed 10%. *Menochilus sexmaculates* (Coleoptera: Coccinellidae) and *Harmonia octomaculata* (Coleoptera: Coccinellidae) also formed 5%. *Temelucha* sp. (Hymenoptera: Ichneumonidae), *Plistospilota guineenis, Chlidonoptera chopardi* (Orthoptera) 5% and Ants (unidentified) 5%.

A total of five species of store-product insect pests were identified. The two most abundant primary insect pests were *Sitotroga cereallela* (Oliver) and *Sitophilus* sp. Secondary insect pests collected in increasing order of abundance were *Gnatocerus maxillosus* (Fab), *Tribolium castaneum* (Herbst) *Rhyzopertha dominica* (Fab) and *Carpophilus dimidiatus* (F). Seven natural enemies were recorded during the storage of grains. These included cereal psocids, parasitic wasps, ants, fire brats, pseudoscopions and spiders.

The study indicated that the overall pest situation in the study area was not alarming, a situation which could be attributed to growing of paddy under shifting cultivation by farmers and the presence of natural enemies.

CHAPTER ONE

GENERAL INTRODUCTION

Rice is a cereal belonging to the family Gramineae (Poaceae) and cultivated as annual crop (Dutta, 1990). Two cutigens commonly grown are *Oryza sativa*, the Asiatic race and *Oryza glaberrima*, the African domesticated rice of local importance. Simmons (1984) and Bor (1979) suggest that rice evolved as a dryland plant on the slopes of the Himalayas. However, Dutta (1990) and Smith (1985) opt for an Indian or tropical origin suggesting that rice began as a plant adapted to low-lying shallow water habitats.

Rice is produced under four main ecologies in Ghana. These are (a) Upland ecology (b) Midland/Hydromorphic ecology (c) Lowland/Inland valley swamp/flood plains ecology and (d) Irrigated ecology.

(a) Upland ecology: In this ecology the crop depends on precipitation (rain-fed) without flooding of field (Farmer, 1982). Rainfall of at least 750 mm for 3-4 months is a critical determinant of its productivity and its amount and distribution determines the cropping season (Onwueme and Sinha, 1991). (b) Midland/Hydromorphic ecology. In this ecology the crop depends on both precipitation and underground water, with periodic flooding of field. Water management is limited to field flooding. (c) Lowland/Inland valley swamp/flood plains ecology. Here the crop depends on precipitation, ground water and flooding from simple water management interventions such as bunds and canals (d) Irrigated ecology: In this ecology the crop depends on intensive and often large scale water management schemes with mechanized pumping or sprinkler and gravity-command systems.

Although rainfed upland ecology constitutes 97% of the total area under cultivation in Ghana, it has been less studied (Pande, 1994). Lowland rice, particularly the irrigated ecology had been more intensively studied for over four decades by the University of Ghana Agricultural Research Station, Kpong, in collaboration with West Africa Rice Development Association (WARDA) and through the international Network for Genetic Evaluation in Rice (INGER) programme (Ministry of Food and Agriculture (MOFA), 1999).

Justification

Demand for rice is increasing in Ghana. Dramatic changes in consumption patterns during the past two decades as well as growth in population combined with rapid urbanization have fueled demand that the country is increasingly failing to meet. Rice production is expected to play a key role in achieving national food security, alleviating rural poverty and contributing to the overall economy through import substitution and conservation of foreign exchange (MOFA, 1999).

Despite the existing high potential for rice production, Ghana imports about 564,000 metric tons of white rice annually compared with domestic production of about 80,000 metric tons (MOFA), 1999). Ghana spent $100 million on rice imports in 1999 (Hon. Minister, MOFA, Verbal Comm.). With the dwindling foreign exchange earnings from the country's export commodities, the urgency for self-sufficiency in local rice production cannot be overemphasized.

The Kwaebibirem district of the Eastern Region of Ghana was selected for the study because it is a rice growing area with a production potential of 1000 metric tons and an installed rice mill which has improved the quality of milled rice in the area.

However gradual increasing incidence of pest damage to the crop have been of great concern to farmers in the community (Ofosu-Budu, unpublished).

It is also possible that if large areas are cultivated and with increased use of insecticides, insects which were not serious pests could become important. This makes it imperative that the insect fauna be studied to enable appropriate control or management decisions to be taken when necessary.

A survey carried out in 1998 indicated that a total of 1013.7 ha of land with a total output of 1.521 tonnes of upland rice was cultivated providing employment opportunities to over 1,666 farmers in and around Kade (Ofosu-Budu unpublished) excluding those in the processing and distribution system. These developments are indicative of the great production potentials of the district. Marketing equally constitutes a great driving force attracting farmers and potential producers by providing the incentive to increase and intensify production. Farmers in the district should therefore be equipped with the necessary information to addressing field and storage production constraints so as to respond to the opportunity offered by the market to earn a higher and more reliable income.

General Objectives

The overall objective of the study was to identify and document insect pests and their natural enemies of upland rice in the Kwaebibirem district of Eastern Region of Ghana. Specific objectives were:

(a) to determine susceptible growth stages of the crop to insect pests damage

(b) to determine the major pests and natural enemies at different crop growth stages and

(c) to determine the population dynamics of pests and their natural enemies, and suggest possible management interventions.

CHAPTER TWO

LITERATURE REVIEW

2.1 Origin and Distribution of Rice

Rice is a major source of energy for a large proportion of the world's population (Smith, 1995). The Genus *Orya* consists of 25 species. Of these only two are cultivated, namely *Oryza satriva* and *Oryza glaberrima* (Onwueme and Sinha, 1991). *O. sativa*, the Asiatic race, has been cultivated in South and East Asia since ancient times, well over 5,000 years ago (Bor, 1979). *O. glaberrima*, the African domesticated rice probably originated in the swampy areas of the Upper Niger river about 1500 B.C. and perhaps near the coast of Guinea to the West at about 1000 BC, approximately 4000 years after the adoption of sorghum in these areas (Simmonds, 1984).

During very early periods, rice spread from India to Southern China and to all the countries of South and East Asia. Rice spread from India to Iran, Syria, Egypt, Italy and Spain (Onwueme and Sinha, 1991). The Portuguese introduced rice into Brazil and the Spaniards introduced it to Central America (Smith, 1995).

2.2 Morphology of rice

Rice is an annual grass with erect culms 60-80 cm tall. It has a shallow root system which is mainly concentrated in the upper soil layer, to a depth of 20-25cm (Buddenhagen and Persley, 1978). The young roots are white, thick, short and relatively unbranched. They elongate with age and produce a dense surface mat. The development of the root system is largely governed by the method of cultivation and nature of soil (Grist and Level, 1969).

The culms are erect, cylindrical and smooth with solid nodes and hollow internodes. The number of internodes varies from 10-20. Buds in the axils of leaves at the lowest nodes grow out to produce tillers. From each node there is one leaf. Each leaf has a lamina and long sheath which completely encircles the internode. The lamina is long (30-50cm) and narrow (12-15cm), usually hairy in *O. sativa* and glabrous in *O. glaberrima* (Steele, 1970).

The inflorescence is loose with many branched panicles. Each branch of the panicle bears one or more spikelets (Purseglove, 1985). The average panicle bears 100-150 kernels. The grain is enclosed by the lemma and palea, which together are called husks or hulls. On threshing, the husks and glumes are removed. The pericarp, aleurone layer and embryo, which are rich in protein and fat, are removed during milling and polishing, leaving mostly the starchy endosperm. The endosperm is usually white or translucent but other colours are also known. The size of the grain varies from 3.5-14.5mm long and from 1.3-2.3mm thick. In certain, cultivars the grain has a characteristic aroma (Onwueme and Sinha, 1991).

2.3 The economic importance of rice

Rice is used mainly for human food and is consumed mostly in the form of whole grains. It is usually cooked by boiling in water or by steaming, and is eaten with pulses, vegetables, fish, meat and stew (Onwueme and Sinha, 1991). Elswhere it is used in the form of parched rice, rice flakes, puffed rice and rice pudding (Dutta, 1990).

Starch made from broken rice is used as laundry starch and in the manufacture of cosmetics and textiles. Beer, wine and spirits are also made from rice. Rice bran has a high oil content (14-17%). The oil which is clear, light-coloured and odourless is used as salad and cooking oil, for soap manufacture, as well as a carrier for insecticides and as an anti-corrosive and rust-resistant oil. Wax can also be obtained from the bran (Bor, 1979).

Rice hulls are used as roughage for cattle feed, chicken litter, ammoniation for fertilizer, filter aid, for floor sweeping and as filler for building materials. Rice hull ash can be used as a source of high-grade silica in the manufacture of building blocks, as an absorbent, soil conditioner a carrier for pesticides and as filler for insulating materials. Rice straw is fed to livestock, for the manufacture of strawboard, hats, mats and for thatching (Onwueme and Sinha, 1991).

2.4 Rice production in Ghana

The trend in rice production in Ghana has been influenced by changes in both the area cropped and productivity. During the 1970s, rice production was relatively stagnant. In the early 1980s the area under rice cultivation dropped from 78000 ha to only about 38000 ha (MOFA, 1999). Available statistics from the regions indicate that the area under rice production has increased substantially in the Upper East, Volta, Ashanti and Western regions in the last ten years. During the same period, however, the areas under rice production in the Northern, Central and Upper West Regions have decreased significantly (MOFA, 1999).

Early attempts made to raise production focused on using high yielding rice varieties. This strategy was flawed since in order to achieve superior yields, the new varieties depended on high levels of management and imported inputs that small scale farmers on rainfed land could not afford (WARDA, 1998).

2.5 Method of cultivation of rice

There are two main systems under which paddy is cultivated; the 'upland' or 'dry' and the 'irrigated' or 'wet' (Grist and Lever, 1969). The terms upland and dry denote rice cultivated as a rain-fed crop under conditions similar to those pertaining to cereals such as wheat. Its cultivation is limited to regions where, in addition to satisfying the plants requirements regarding light and temperature, rainfall is not less than 750mm distributed over a growing period of three to four months (Mikkelsen and Evatt, 1966). In the wet system, the land is inundated and the crop is grown in water from time of planting until the approach of harvest, the water for this purpose supplied either by flooding during the rainy season or by planting the crop in naturally swampy land or by controlled irrigation (Grist, 1983).

2.6 Constraints to Rice Production

A number of environmental and agronomic problems such as weeds, declining soil fertility, diseases, insects and vertebrate pests are considered major constraints to rice production in Ghana (Afreh-Nuamah, 1996). Pressure from these constraints tend to promote increased use of pesticides that create serious environmental problems.

2.7 Insect Fauna of upland rice

The rice plant is vulnerable to attack by various kinds of insects. Although some sixty insect species have been reported as pests throughout Africa, few have been studied in details (Buddenhagen and Persley, 1978). The upland rice ecology is characterized by the assemblage of (a) insect pests and (b) their natural enemies.

(a) Insect Pests

Insect pests cause extensive damage to the crop from seedling stage to the ripening stage as well to the grain during storage (Juo and Lowe, 1985). These insect pests may be grouped on the basis of their feeding habits.

Soil borne insects such as *Solenopsis geminata* (Hymenoptera: Formicidae). *Gryllotalpa africana* (Orthoptera: Gryllotalpidae), *Messor barbarus* (Hymenoptera: Formicidae), *Gonocephalum* (Coleoptera: Tenebrionidae) and white grubs feed on roots of upland rice seedling (Pande, 1994). Termites (several unidentified species) cut young plants at the ground, cover them with earth to be consumed completely later on (Breniere, 1983).

Economic damage in the vegetative phase is caused by both lepidopterous and dipterous stemborers. The most important species are *Chilo* sp (Lepidoptera: Pyralidae), *Sesamia* sp (Lepidoptera: Noctuidae), *Maliarpha separatella* (Lepidoptera: Pyralidae), *Scirpophaga* sp (Lepidoptera: Pyralidae), and *Diopsis thoracica* (Diptera: Diopsidae). These insects form the most important group from an economic stand point and there is virtually no paddy field which is free from them (Steele, 1970). Their larvae tunnel into the stem after killing the main shoot leading to dead heart (Blay *et al*, 2000).

In the reproductive phase *Aspavia armigera* (Heteroptera: Pentatomidae), *Nezara viridula* (Heteroptera: Pentatomidae), *Oebalus pugnax*, (Heteroptera: Pentatomidae), *Diploxis fallax* (Heteroptera: Pentatomidae) and *Stenocoris apicalis* (Heteroptera: Alydidae) cause serious damage to grains on the field (Breniere, 1983). These grain suckers may destroy grains partially or completely resulting in empty grains (Hollay *et al*, 1987).

Paddy and rice in storage are subject to attack by insects, fungi, mites and rats at all levels. In Ghana eighteen insect pests have been identified to attack paddy and rice in storage (Boakye *et al* unpublished).

The major ones in decreasing order of importance are; *Sitotroga cereallela* (Lepidoptera: Elechiidae), *Sitophilus oryzae* (Coleoptera: Curculionidae), *Rhyzopertha dominica* (Coleoptera: Bostrichidae), *Tribolium castaneum* (Coleoptera: Tenebrionidae) and *Corcyra cephalonica* (Lepidoptera Pyralidae). Others include *Oryzaephilus* sp (Coleoptera: Silvanidae), *Cryptolestes* sp (Coleoptera: Cucujidae), *Ephestia cautella* (Lepidoptera: Pyralidae) and *Gnatocerus maxillousus* (Coleoptera: Tenebrionidae), Nakakita (1998) had reported *Plodia interpunctella* (Lepidoptera: Pyralidae), *Lasioderma serricorne* (Coleoptera: Anobiidae) and *Carpophilus* sp (Coleoptera: Nitidulidae) as major insect pests of rice in Japan.

Damage takes the form of holes and cavities within grains and is often distinctive to the species or family to which the pest belongs (Walker, 1992), *Sitophilus* and *Sitotroga* species for example can attack the paddy in the field prior to harvest, spending their pre-adult life concealed within a grain, making them difficult to detect by visual inspection (Walker, 1992).

(b) Natural Enemies

There are rich communities of beneficial insects, spiders and diseases that attack insect pests of rice. The beneficial species often control insect pests, especially in places where use of broad-spectrum pesticides is avoided (Shepard *et al*, 1991). Natural enemies in the rice ecology may be grouped as predators, parasitoids and pathogens. The major groups of the latter are fungi, viruses, bacteria and nematodes.

Important predators in rice fields include *Micraspis* sp (Coleoptera: Coccinellidae), *Ophionea nigrofasciata* (Coleoptera: Carabidae), *Cyrtorhunus* sp (Hemiptera: Miridae), *Polytoxus fuscovittatus* (Hemiptera: Reduviidae), *Agriocnemis* sp (Odonata: Coenagrionidae) and *Panstenon* sp (Hymenoptera: Pteromalidae). These organisms mostly feed on eggs and larvae of plant hoppers, leafhoppers, moths and butterflies. Others are *Tetragnatha* sp (Araneae: Tetragnathidae), *Araneus insustus* (Araneae: Araneidae), *Phidippus* sp (Araneae: Salticidae) and *Lycosa pseudoannulata* (Araneae: Lycosidae) feed on a range of adult insect pests including stem borer moths (Sherpard *et al* 1991).

Telenomus sp, (Hymenoptera: Scelionidae), *Gonatocerus* sp (Hymenoptera: Mymaridae), *Anagyrus* sp (Hymenoptera: Mymaridae), *Oligosita* sp (Hymenoptera: Trichogrammatidae) and *Psix lacumatus* (Hymenoptera: Scelionidae) parasitize eggs of moths and bugs. *Itoplectis narangae* (Hymenoptera: Ichneumonidae), *Trichomma cnaphalocrosis*, *Charops hrachypterum*, *Xanthopinpla flayolineata* and *Cotesia* sp (Apanteles) (Hymenoptera: Braconidae) are found in most rice environments as larval parastitoids of leaf folders and stem borers (Shepard, *et al* 1991, Claridge, 1990). These insects play an important part in the overall field mortality of insect pests. In Ghana not much is known about the natural enemies. However Afreh-Nuamah (1996) identified a variety of natural enemies on irrigated rice with very promising potentials in reducing insect pest population.

2.8 Control of Insect Pests of Rice

Upland rice insect pests can be controlled by cultural methods, chemical methods, use of resistant varieties and biological control methods (Breniere, 1983).

2.9 Cultural Control of Rice Insect Pests

Cultural control involves farmers making group decisions and implementing some of the following practices (i) Early and synchronous planting (ii) ploughing the soil when it is wet or soon after rice harvest (iii) Increased seed density and (iv) Intercropping (Pande, 1994). (i) Early and synchronous planting of early-maturing rice varieties. This can help to protect the crop from seedling maggots and white grubs most of which show some seasonal predictability either by avoiding the egg-laying period of the pest or by allowing the crop to reach an age where they are resistant by the time the pest appears (Van Emden, 1996). (ii) Ploughing the soils when it is wet or soon after rice harvest. Many insects live or hibernate in suitable temperature and humidity conditions relatively near the soil surface. These conditions can be disturbed by ploughing, which creates temporary-drought conditions in the upper soil layers and may expose larvae and pupae of root beetles and cutworms to the full radiation of the sun. Many of these insects may be eaten by birds and other natural enemies. Other pupae and eggs may be buried by ploughing to a depth from which they fail to reach the soil surface after emerging, while some will be killed mechanically by rough contact with soil chips. (iii) Increasing seed density can help achieve a good plant stand and also have a considerable effect on pest problems. Fewer insects exist in dense rather than sparse stands (Van Emden, 1996). Densely sown seeds compensates for loss due to damage by foraging insects, rodents and birds. (iv) Intercropping in certain situations can decrease pest damage to rice. The intercrop provides shelter and humid conditions near the ground thereby encouraging ground-living predators. Host plant-finding behaviour of insect pest may also be disrupted by the close juxtaposition of two plant species, consequently aerial feeding pests such as stem borers and hoppers may find it difficult to increase their population.

Other cultural practices such as fertilizer application and mulching have an effect on the insect population of certain species (Surajit, 1981). The application of fertilizers to maintain growth often helps paddy plants to 'get away' early and so avoid heavy insect damage. Thus, injury by the gall midge, *Pachydiplosis oryzae* (Wood-Mason), is kept under control in India and Pakistan by means of top dressing of ammonium sulphate, which stimulates the growth of tillers (Grist and Lever, 1969).

Resistant rice varieties developed from the interspecific crossing of African glaberrimas and Asian sativas that are resistant to rice stemborers and the African rice gall midge amoung other stress resistant/tolerant characteristics are available (WARDA, 1999). In Brazil, varieties tolerant of *Elasmophalpus lignosellus* and resistant to *Diatrraea saccharalis* have been identified (Pande, 1994). In Cuttack (India), among upland varieties, Sathika, JBS 508, Mutant 57, Kesari and Vagai were found to be resistant to the rice bug, *Leptocorisa* sp (Swason and Newsome, 1962).

2.10 Chemical Control of Rice Insect Pests

In most parts of Africa, where rice is grown on uplands with only one crop in a season, the chance of a big build up of pests is at a minimum (Steele, 1970). However with improved productivity of upland rice and in order to contain epidemics, the use of insecticides may be justified (Shepard, 1990). Currently in Ghana, there are no recommended chemical control methods. However occasionally when defoliators, grain suckers and armyworms abound on irrigated rice insecticides such as Karate, Furadan and Dursban respectively are used by the local farmers (Afreh-Nuamah, 1996). Pande (1994) has provided some information on chemical control practices against upland rice insect pest.

Seed treatment with Carbofuran or Endosulfan at 0.5-1 kg/100kg seed is effective against ants, termites, beetles.

Soil treatment at the time of field preparation with 20-30 kg of 10% BHC or Aldrin 3% methyl parathion dust can control rice seedling flies, mole crickets and root aphids.

Foliar spray of chlorpyrifos, endosulfan, dichlorovos, monocrotophos at 0.3-0.4 kg a.i/ha directed at the site of feeding is effective in controlling leaf folders, gall midges, grasshoppers, mealy bugs, cutworms and stem borers. Foliar spray at 0.3-0.4 kg a.i/ha directed at site of feeding can control leaf hoppers and plant hoppers. Dusting 5 or 10 percent HBC at 15-25kg/ha in evening hours can control rice bugs.

In storage, protection from insect pests may be ensured by the use of insecticides on the walls and floor of premises before filling with grains (Grist and Lever, 1969). However because of health hazards, both to man and domestic animals, the use of a very limited range of insecticides is permitted.

In Ghana, the use of some insecticides for example Lindane and Carbofuran are severely restricted while Aldrin and Parathion Methyl are provisionally banned (Blay *et al,* 2000).

2.11 Biological Control of Rice Insect Pests

The natural balance between insect pests and their natural enemies is often disrupted by indiscriminate use of broad-spectrum insecticides. Although insecticides are needed in some cases, they should be used judiciously in order to save vulnerable natural control agents (Sherpard *et al*, 1991). If reliable pest management strategies are to be developed, some combination of varietal resistance and biological control should provide the solution (Way, 1990).

In recent years detailed studies in the field on the population dynamics of plant hoppers have demonstrated a significant role for natural enemies. Kenmore *et al* (1984), showed that several groups of predators, particularly the assemblage of spiders, in rice fields in the Philippines may respond numerically to plant hopper density, *Trichogramma* sp have been reared from *Diopsis* eggs while species of *Aprostocetus* and *Trichopria* have also been reared from the pupae. However, information on biological control in upland situation is scanty (Pande, 1994).

2.12 Vertebrate Pests of Rice

Rodents are among the vertebrate pests that cause the most serious damage to rice in the field. They feed on the crop from sowing to harvest (Pearman, 1990). Elsewhere, the field rat, *Rattus rattus* and the small house mice (*Mus musculus*) are serious pests of rice (Steele, 1970; Walker, 1992).

Thryonomis swinderianus is widespread in Africa and it is considered as one of the main pests affecting rice in Ghana, Nigeria, Sierra Leone and the Ivory Coast. In Nigeria, it is estimated that in a single night one grasscutter is capable of destroying five hundred (30 to 60 day old) stems (Breniere, 1983).

Rodents can be controlled using poisoned bait made up of rice or paddy bran and anti-coagulants (coumarine) or Endrine (Breniere, 1983). Fencing with palm fronds, wire mesh etc. is a common method in Ghana for improving protection of paddy fields. Elsewhere excluding rodents from rice fields with an electrified fence has been developed (Pande, 1994).

Birds are also troublesome and often serious in rice fields especially where there is plenty of adjacent cover. The loss of grain to bird damage is the greatest retarding factor to expanding world production (Grist and Lever, 1969). The paddy field is a particularly suitable environment for permanent aquatic birds as well as many migratory species of the palearctic region. (Breniere 1983). On irrigated rice in Ghana, damage to rice is caused by weaver birds and the *Quelea quelea* while the colourful 'Red' and 'Yellow' bishops do not cause any damage but rather they attract grain eating birds to the field for a meal (Afreh-Nueamah, 1996).

Bird control measures fall basically into three categories. (i) wholesale destruction of pest species (ii) bird scaring devices and (iii) crop management. Measures used to date in Ghana have fallen in category (ii). Some of the ways of scaring them include throwing stones using catapult, shouting, cracking whips and agitating a network of cords stretched over rice farms with noisy objects such as tins containing a few stones. In practice, children are employed for bird scaring (Steele, 1970).

CHAPTER THREE

FIELD INSECT FAUNA OF THE RICE PLANT

Introduction

A wide range of insect species attack different parts of the rice plant at different stages of growth. The leaves, stems and even the grains are seriously attacked. The extent of damage depends on the stage of growth of the plant when infestation occurred, the pest species and the level of pest population. Often it is the latter which determines the pest status of a given species as those species which are capable of rapid multiplication can cause total destruction of a crop (Smith *et al* 1986).

The objectives of the study were to determine (i) the major pests and natural enemies of upland rice at different growth stages of the crop, (ii) the population dynamics of the pests and their natural enemies.

3.0 Materials and Methods

Study site

The study was conducted in the Kwaebibirem District of the Eastern region of Ghana (Fig. 1). It is located in the moist deciduous forest with wet semi-equatorial climate where the annual rainfall is between 1250 mm and 1750 mm. The dry seasons are clearly marked and the area is drained by the river Birim (Dickson and Benneh, 1983) and characterized by upland/valley bottom conditions.

Insects were collected from experimental fields at the university of Ghana Agriculture Research Station (ARS)-Okumanin and farmers fields at Subi, Abodom, Pramkese and Abaam Fig 2.

FIG 1. MAP OF GHANA SHOWING THE TEN REGIONS AND THE KWAEBIBIREM DISTRICT

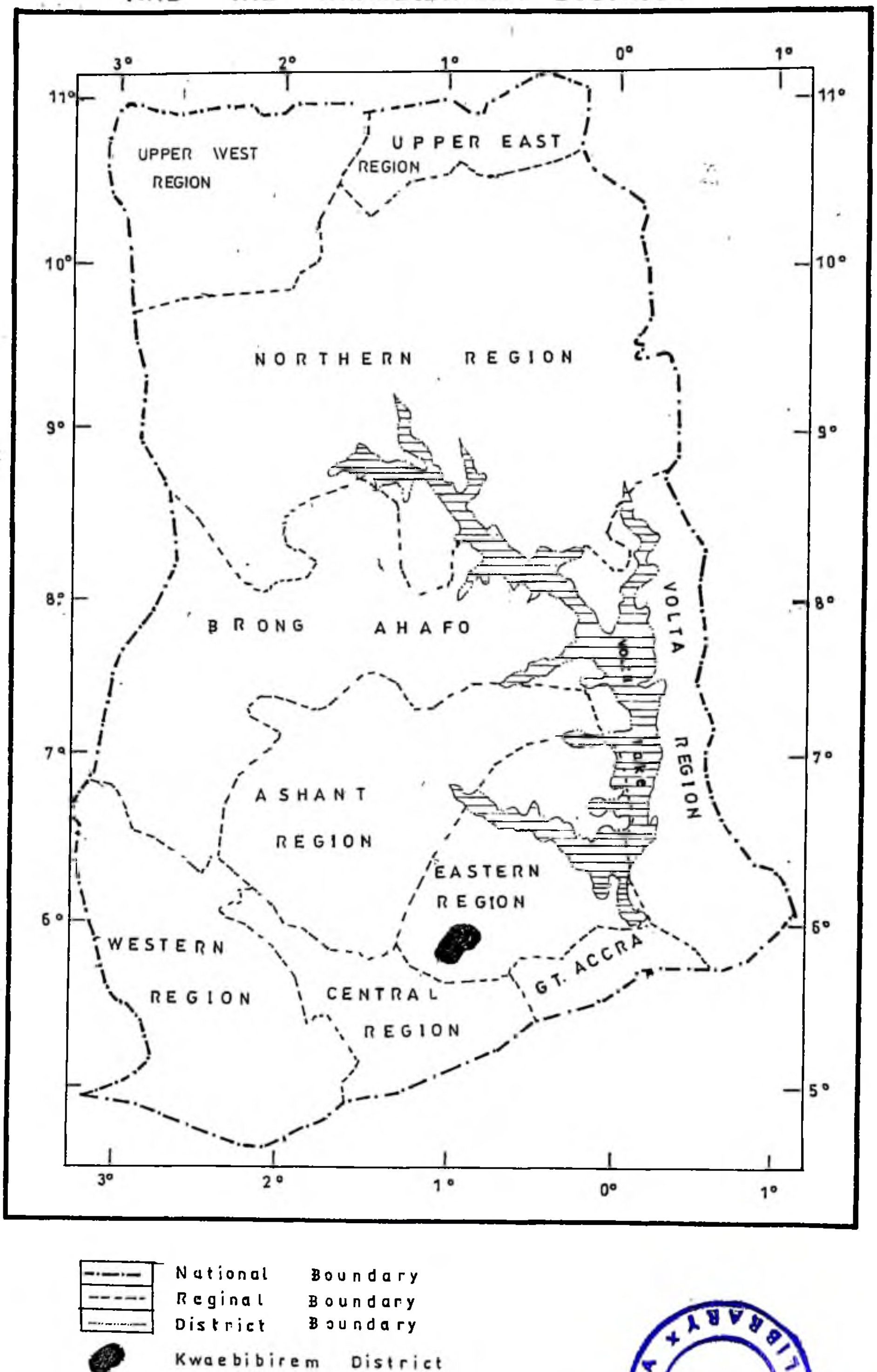
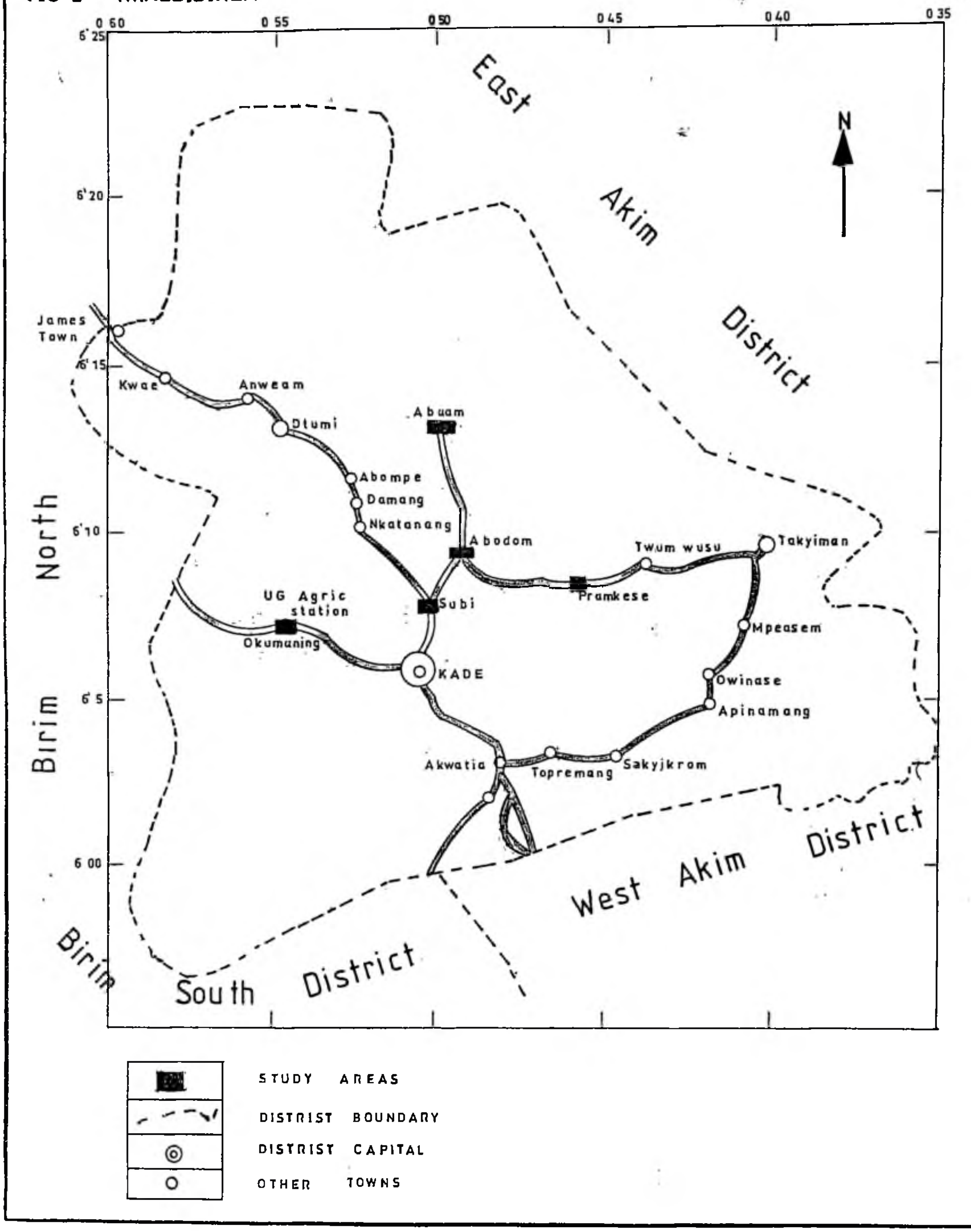


FIG 2. KWAEBIBIREM DISTRICT SHOWING STUDY AREAS



3.1 Preparation of Rice Fields and Planting

A plot of flat land 50 metres by 100 metres (experimental farm) was cleared manually and burnt for sowing in April 2000 at ARS-Okumanin. The field was sown with the rice variety CT9199 by dibbling. Spacing was 45cm x 15cm. Five to seven seeds were dropped into each hole and then covered with soil.

NPK was applied at 558gm per plot of 114m^2 at panicle initiation stage. There were thirty six of such plots. Weeds were controlled by the application of propanil plus 2, 4-D at 2.5 liters per acre at seedling stage and then manually at tillering stage. No insecticide was applied.

In addition, one farm measuring 50 metres by 100 metres each, belonging to a farmer was selected at Subi, Abodom, Abaam and Pramkese. The fields were cleared manually, burnt and sown by random dibbling in March 2000. The fields were sown with the common variety "Abidjan". Five to seven seeds were dropped in each hole which were then covered with soil. Weeds were controlled by the farmers with mixtures of the weedicides, Bentazon, Gallon and common salt at 2 1 per acre at seedling stage. No insecticide or fertilizer was applied by farmers.

3.2 Insect Collection

Field insects were collected weekly. Collection was started one week after sowing and continued for a period of 12 weeks. Insects were collected between 9.00 am and 11.30 am when most insects were very active on the field.

Two line transects 100 metres long and 25 metres apart were fixed through each rice field (experimental and selected farms) using wooden pegs. On the first line transect, insects were collected by walking the entire length of 100 metres and sweeping insects sighted on the tillers along the transect. All the insects trapped in the sweep net were removed and placed in 70% alcohol in plastic jars with lids.

Insects crawling on the ground were picked with forceps and also preserved in 70% alcohol. The preserved insects were taken to the laboratory for identification.

On the second line transect ten hills (of between 9 to 14 tillers), ten meters apart were marked along the line using wooden pegs. The tillers of each marked hill were examined every week. Insects found on the tillers were counted and recorded as pests, natural enemies or neutral insects depending on whether they feed on rice plant, on other insects or did not interact with neither rice plant nor other insects. The activity of birds and rodents were monitored by direct observation on the field.

3.3 Assessment of Insect Damage

The type of damage caused by insect pests were deterimined by visual observation in caged hills on the field. The cages which were constructed of wooden frames measured 1.5 m x 0.45m x 0.45m. The frames were covered with yellow nylon nets on five sides (plate 1). Insect pests whose activity and damage were not clear were trapped and released into the cages and observed. These insects were grouped as pests, natural enemies or neutral insects.

3.4 Identification of Insect Species

The collected insects were identified using the reference collections of the Entomology Museum of the Department of Zoology, University of Ghana, field guides and taxonomic keys (Donald and Richard, 1970; Serle and Morel, 1992; Bland and Jagues 1978).

Pests and natural enemies were grouped for the different growth stages of the rice plant at each of the study areas after identification. Their numbers were summed for each sampling week.

Plate 1. Paddy field showing insect cage

3.5 Results

3.5.1 Seedling Stage

At all the study sites four main insect pest species were found on rice seedlings (Tables 1-4). These were identified as the stalk eyed borer, *Diopsis thoracica*, the meadow grasshopper, *Conocephalus longipennis* and termites, *Odontotermes* sp. The Larvae of *D. thoracica*, a stem borer and an endophagous (feeds on internal tissue) diptera detillered the rice plant resulting in dead heart. *C. longipennis* a defoliator, caused damage by feeding on the leaves of tillers. *Odontotermis* sp. destroyed seedlings by cutting them at the ground level and in some cases cover them with earth (table 5).

Anaxipha and *Phidippus* species were predators collected at this stage. The *Anaxipha* sp preyed on eggs, small larvae and nymphs of planthoppers while *Phidippus* sp preyed on adults of Diopsis (Table 6).

3.5.2 Tillering Stage

At this stage pests included *D. thoracica*, *Odontotermis* sp., *C. longipennis* and five species of grasshoppers. These were *Turbida* sp, *Acrida* sp, *Cataoptropteryx* sp, *Taphoronota* sp and *Zonocerus variegatus* (Plate 2). The grasshoppers were defoliators causing damage by chewing leaves especially at the edges *Campylenchia latipes* sp. (Homoptera, Memberacidae), a leaf sucker also fed on sap, causing leaf necrosis.

There was an increase in the number of species of natural enemies from two at the seedling stage to ten at the tillering stage. The species were *Anaxipha* sp. And *Phidippus* sp. They preyed on eggs, small larvae, nymphs and adult *Diopsis*. Other natural enemies were observed included two species of Lady beetles i.e. *Menochilus sexmaculatus* and *Harmonia octomaculata,* two species of dragonfly i.e. *Palplopluera lucia* and *Orthetrum stammate*, two species of damselfly,

Plate 2. Key field insect pests of upland rice

Diopsis thoraciaca

Zonocerus variegatus

***Taphronota* sp**

***Oebalus* sp**

Enallagma sp, *Agriocnemis* sp and several unidentified ant species. The dragonflies and the damselflies fed on adult *Diopsis* which the Lady beetles preyed on egg masses of ants.

Table 1: Pests and natural enemies at various growth stages of upland rice at ARS – Okumanin/Kade

Growth Stage	Pest	Natural Enemies
Seedling	*Diopsis thoracica*, *Conocephalus longipennis*	*Phidippus* sp. *Anaxipha* sp
Tillering	*Diopsis, thoracica*,, *Conocephalus longipennis*, *Turbida* sp. *Acrida* sp *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes*	*Phidippus* sp, *Menochilus sexmaculatus*, *Anaxipha* sp. *Harmonia octomaculata*, *Palplopluera lucia*, *Orthetrum stemmate*, *Enal lagma* sp, *Agriocnemis* sp, Ants, Orb spiders
Panicle development	*Diopsis, thoracica*,, *Conocephalus longipennis*, *Turbida* sp. *Acrida* sp *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes* *Taphronota* sp.	*Phidippus* sp, *Menochilus sexmaculatus*, *Anaxipha* sp. *Harmonia octomaculata*, *Palplopluera lucia*, *Orthetrum stemmate*, *Enal lagma* sp, *Agriocnemis* sp, *Euborellia* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, *Temelucha* sp *Argyrophylax* sp. Ants. Orb spiders
Heading-flowering	*Diopsis, thoracica*,, *Conocephalus longipennis*, *Turbida* sp. *Acrida* sp *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes* *Taphronota* sp.	*Phidippus* sp, *Menochilus sexmaculatus*, *Anaxipha* sp. *Harmonia octomaculata*, *Palplopluera lucia*, *Orthetrum stemmate*, *Enal lagma* sp, *Agriocnemis* sp, *Euborellia* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, *Temelucha* sp *Argyrophylax* sp. Ants. Orb spiders
Milky-soft dough	*Diopsis, thoracica*,, *Conocephalus longipennis*, *Turbida* sp. *Acrida* sp *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes* *Aspavia* sp. *Oebalus* sp. *Nezara* sp. *Trichispa* sp. *Lonchura cucullatus*, *Vidua macroura*.	*Phidippus* sp, *Menochilus sexmaculatus*, *Anaxipha* sp. *Harmonia octomaculata*, *Palplopluera lucia*, *Orthetrum stemmate*, *Enallagma* sp, *Agriocnemis* sp, *Euborellia* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, *Temelucha* sp *Argyrophylax* sp. Ants. Orb spiders
Hard dough-maturity	*Diopsis, thoracica*,, *Conocephalus longipennis*, *Turbida* sp. *Acrida* sp *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes* *Aspavia* sp. *Oebalus* sp. *Nezara* sp. *Trichispa* sp. *Lonchura cucullatus*, *Vidua macroura*, *Ploceus* sp.	*Phidippus* sp, *Menochilus sexmaculatus*, *Anaxipha* sp. *Harmonia octomaculata*, *Palplopluera lucia*, *Orthetrum stemmate*, *Enallagma* sp, *Agriocnemis* sp, *Euborellia* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, *Temelucha* sp *Argyrophylax* sp. Ants. Orb spiders

Table 2: Pests and natual enemies at various growth stages of upland rice at Subi/Abodom

Growth Stage	Pest	Natural Enemies
Seedling	*Diopsis thoracica, Conocephalus longipennis, Odontotermis* sp	*Phidippus* sp. *Anaxpha* sp
Tillering	*Diopsis thoracica, Conocephalus Longipennis, Turbida* sp *Zonocerus variegates, Cataoptropteryx* sp *Campylenchia latipes, Odontotermis* sp.	*Phidippus* sp. *Menochilus sexmaculatus, Harmonia octomaculata, Palplopluera lucia, Orthetrum stemmate. Enallagma* sp. *Agriocnemis* sp. Ants. Orb spiders
Panicle development	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Zonocerus variegatus, Cataoptropteryx* sp *Campylenchia latipes, Odontotermis* sp. *Ratus* sp. *Thryonomys* sp.	*Phidippus* sp. *Menochilus sexmaculatus, Harmonia octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp. *Agriocnemis* sp. *Plistopilota guineenis,* Ants. Orb spiders *Chlidonoptera chopardi.*
Heading-flowering	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Zonocerus variegatus, Cataoptropteryx* sp *Campylenchia latipes, Odontotermis* sp. *Ratus* sp. *Thryonomys* sp.	*Phidippus* sp. *Menochilus sexmaculatus, Harmonia octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp. *Agriocnemis* sp. *Plistopilota guineenis,* Ants. Orb spiders *Chlidonoptera chopardi*
Milky soft-dough	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Zonocerus variegatus, Cataoptropteryx* sp *Campylenchia latipes, Odontotermis* sp. *Taphronota* sp *Aspavia* sp. *Oebalus* sp. *Nezara* sp. *Trichispa* sp. *Rattus* sp. *Thryonomys* sp. *Lonchura cucullatus, Vidua macroura.*	*Phidippus* sp. *Menochilus sexmaculatus, Harmonia octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp. *Agriocnemis* sp. *Plistopilota guineenis,* Ants. Orb spiders *Chlidonoptera chopardi*
Hard dough-maturity	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Zonocerus variegatus, Cataoptropteryx* sp *Campylenchia latipes, Odontotermis* sp. *Taphronota* sp *Aspavia* sp. *Oebalus* sp. *Nezara* sp. *Trichispa* sp. *Rattus* sp. *Thryonomys* sp. *Lonchura cucullatus, Vidua macroura. Ploceus* sp	*Phidippus* sp. *Menochilus sexmaculates, Harmonia octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp. *Agriocnemis* sp. *Plistopitota guineenis,* Ants. Orb spiders *Chlidonoptera chopardi*

Table 3: Pests and natural enemies at various growth stages of upland rice at Abaam

Growth Stage	Pest	Natural Enemies
Seedling	*Diopsis thoracica*, *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp	*Phidippus* sp, *Anaxipha* sp
Tillering	*Diopsis thoracica*, *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp, *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes*, *Rattus* sp, *Thryonomys* sp	*Phidippus* sp, *Menochilus sexmaculates*, *Harmonia octomaculata*, *Palplopluera lucia* *Orthetrum stemmate*, *Enallagma* sp *Agriocnemis* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, Ants, orb spiders
Panicle development	*Diopsis thoracica*, *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp, *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes*, *Rattus* sp, *Thryonomys* sp	*Phidippus* sp, *Menochilus sexmaculates*, *Harmonia octomaculata*, *Palplopluera lucia* *Orthetrum stemmate*, *Enallagma* sp *Agriocnemis* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, Ants, orb spiders *Temelucha* sp *Euborellia* sp *Argrophylax* sp
Heading-flowering	*Diopsis thoracica*, *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp, *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes*, *Rattus* sp, *Thryonomys* sp *Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates*, *Harmonia octomaculata*, *Palplopluera lucia* *Orthetrum stemmate*, *Enallagma* sp *Agriocnemis* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, Ants, orb spiders *Temelucha* sp *Euborellia* sp *Argrophylax* sp
Milky soft-dough	*Diopsis thoracica*, *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp, *Zonocerus variegatus*, *Cataoptropteryx* sp *Campylenchia latipes*, *Rattus* sp, *Thryonomys* sp, *Aspavia* sp *Oebalus* sp *Nezara* sp, *Trichispa* sp, *Lonchura cucullatus*, *Vidua macroura*, *Taphronota* sp.	*Phidippus* sp, *Menochilus sexmaculates*, *Harmonia octomaculata*, *Palplopluera lucia* *Orthetrum stemmate*, *Enallagma* sp *Agriocnemis* sp. *Plistopilota guineenis*, *Chlidonoptera chopardi*, Ants, orb spiders *Temelucha* sp *Euborellia* sp *Argrophylax* sp

Hard dough-maturity	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp, *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp *Campylenchia latipes, Rattus* sp, *Thryonomys* sp, *Aspavia* sp *Oebalus* sp *Nezara* sp, *Trichispa* sp, *Lonchura cucullatus, Vidua macroura, Ploceus* sp *Taphronota* sp.	*Phidippus* sp, *Menochilus sexmaculates, Harmonia octomaculata, Palplopluera lucia Orthetrum stemmate, Enallagma* sp *Agriocnemis* sp. *Plistopilota guineenis, Chlidonoptera chopardi,* Ants, orb spiders *Temelucha* sp *Euborellia* sp *Argrophylax* sp

Table 4: Pests and natural enemies at various growth stages of upland rice at Pramkese

Growth Stage	Pest	Natural Enemies
Seedling	*Diopsis thoracica, Conocephalus longipennis, Odontotermis* sp,	*Anaxipha* sp *Phidippus* sp,
Tillering	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp, *Campylenchia latipes* sp, *Odontotermis* sp, *Thryonomys, Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates, Harmonia Octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp, *Agriocnemis* sp, *Plistopilota guineenis, Chlidonoptera chopardi,* Ants
Panicle development	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp, *Campylenchia latipes Thryonomys, Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates, Harmonia Octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp, *Agriocnemis* sp, *Plistopilota guineenis, Chlidonoptera chopardi,* Ants, *Temelucha* sp, *Euborellia* sp, *Argrophylax* sp, Orb spiders.
Heading-flowing	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp, *Campylenchia latipes Thryonomys, Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates, Harmonia Octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp, *Agriocnemis* sp, *Plistopilota guineenis, Chlidonoptera chopardi,* Ants, *Temelucha* sp, *Euborellia* sp, *Argrophylax* sp, Orb spiders.
Milky soft-dough	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp, *Campylenchia latipes Aspavia* sp *Oebalus* sp, *Nezara* sp, *Trichispa* sp, *Thryonomys,* sp, *Lonchara cucullatus, Vidua macroura, Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates, Harmonia Octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp, *Agriocnemis* sp, *Plistopilota guineenis, Chlidonoptera chopardi,* Ants, *Temelucha* sp, *Euborellia* sp, *Argrophylax* sp, Orb spiders.

Hard Dough-Maturity	*Diopsis thoracica, Conocephalus longipennis, Turbida* sp *Acrida* sp, *Zonocerus variegatus, Cataoptropteryx* sp, *Campylenchia latipes Thryonomys* sp, *Aspavia* sp, *Oebalus* sp, *Nezara* sp, *Trichispa* sp, *Thryonomys* sp, *Lonchara cucullatus, Vidua macroura, Ploceus* sp, *Taphronota* sp	*Phidippus* sp, *Menochilus sexmaculates, Harmonia Octomaculata, Palplopluera lucia, Orthetrum stemmate, Enallagma* sp, *Agriocnemis* sp, *Plistopilota guineenis, Chlidonoptera chopardi,* Ants, *Temelucha* sp, *Euborellia* sp, *Argrophylax* sp, Orb spiders.

Table 5: Damage caused by field pests of upland rice

A. Insects

Species	**Order**	**Family**	**Damage**
Diopsis thoracica	Diptera	Diopsidae	Dead heart
Conocephalus longipennis	Orthoptera	Tettigonidae	Defoliation
Turbida sp	Orthoptera	Cyrtacanthacridine	Defoliation
Acrida sp	Orthoptera	Acridinae	Defoliation
Catoptropteryx sp	Orthoptera	Catotropteryx	Defoliation
Taphronota sp	Orthoptera	Acrididae	Defoliation
Zonocerus variegatus	Orthoptera	Acrididae	Defoliation
Aspavia sp	Heteroptera	Pentatomidae	Mottle grain
Nezara sp	Heteroptera	Pentatomidae	Mottle grain
Oebalus sp	Heteroptera	Pentatomidae	Mottle grain
Odontotermes sp	Isoptera	Termitidae	Cut stems
Trichispa sp	Coleoptera	Chrysomelidae	Mottle grain
Campylenchia latipes	Homoptera	Membracidae	Brown leaf spots

B. Rodents

Species	**Common name**	**Family**	**Damage**
Rattus sp	Field rat	Muridae	Cut off stem
Thryonomys sp	Grasscutter	Thryanomidae	Cut off stem

C. Birds

Species	**Common name**	**Family**	**Damage**
Ploceus sp	Village weaver	Ploceidae	Empty panicle
Lonchora cucullatus	Bronze manikin	Estrididae	Empty panicle
Vidua macrouca	Whydah	Ploceidae	Empty panicle

Table 6: Natural enemies and their function

Species	Order	Target organism
Anaxipha sp	Odonata	Prey on eggs, small larvae of ants
Palplopluera lucia	Odonata	Prey on *Diopsis* & flying insects
Orthetrum stammate	Odonata	Prey on *Diopsis* & flying insects
Enallagma sp	Odonata	Prey on small flying insects
Agriocnemis sp	Coleoptera	Prey on small flying insects
Menochilus sexmaculatus	Coleoptera	Prey on small larvae & eggs of ants
Harmonia octomaculata	Dermaptera	Prey on small larvae & eggs of ants
Euborellia sp	Diptera	Prey on stem borer larvae
Argyrophylax sp	Hymenoptera	Parisitize small larvae
Temelucha sp	Orthoptera	Paristize stem borer larvae
Plistospilota guineenis	Orthoptera	Prey on nymphs and adult grasshopper and *Diopsis*
Chlidonoptera Chopardi	Araneae	Prey on nymphs and adult grasshopper and *Diopsis*
Phidippus sp	Araneae	Prey on nymphs and adult grasshopper and *Diopsis*
Orb Spiders (unidentified)	Araneae	Prey on nymphs and adult grasshopper and *Diopsis*
Ants (unidentified)	Hymenoptera	Prey on eggs and larvae of plant hoppers

3.5.3 Panicle Development Stage

Eight insect pest species were recorded. These were *D. thoracica*, *C. longipennis*, *Turbida* sp, *Acrida* sp, *Taphronota* sp *Cataptropteryx* sp. *Z variegates* and *C. latipes* were the defoliators recorded. At four of the experimental sites i.e. Subi, Abodom, Abaam and Pramkese rodents caused damage to the crop through their feeding activities. *Rattus* sp and *Thryonomys* sp, cut the stems of the rice plant at ground level and fed on the stems and leaves.

Natural enemies collected included *Palplopluera lucia, orthetrum stemmate, Menochilus sexmaculatus, Harmonia octomaculata,* Ants, the jumping spiders and Orb spiders (Plate 3). *Argyrophylax* sp parasitized stem borer larvae. Two species of praying mantis, *Plistospilota guineenis* and *Chlidonoptera chopardi* were observed for the first time at this stage. These predators fed on nymphs, adult *Diopsis* and other insects.

3.5.4 Heading – Flowering Stage

Defoliators and detillerers at the vegetative growth stage continued to attack the crop. *D. thoracica*, *C. longipennis*, *Turbida* sp, *Acrida* sp, *Cataptropteryx* sp, *Taphronota* sp, *Z. variegatus* and *C. latipes* were observed. Bees and wasps were found feeding on the pollen. At this stage the *Thryonomys* sp also fed on the stems and leaves of the rice plant.

Natural enemies were also the same as those observed at the panicle stage. The predators were *Palplopluera lucia*, *Orthetrum stammate*, *Enaalagma* sp, *Agriocnemis* sp, *plistospilota guineenis*, *Chlidonoptera chopardi*, *Menochilus sexmaculatus*, *Harmonia octomaculata*, Jumping spider, Orb spider and Ants. The Tachinid fly was the only parasitoid found. Earwigs and *Temelucha* sp a (wasp) were collected for the first time. *Temelucha* sp (*Hymenptera*: *Ichneumonidae*) parasitized *Diopsis* larvae while the Earwig (Dermaptera: Carcinophoridae) preyed on larvae of *Diopsis* sp.

3.5.5 Milky – Soft Dough Stage

This was a critical stage where developing grains were vulnerable to insect attack. The activities of defoliators and detillerers were less prominent. Grain sucking insects pests in order of increasing importance were, *Oebalus* sp *Aspavia* sp and *Nezara* sp all of the order Heteroptera and family Pentatomidae. *Trichispa* sp fed on the soft grains. The feeding activity of *Trichispa* sp predisposed the grains to attack by fungus which become very conspicuous at the grain maturity stage. The feeding activities of *Thryonomys* sp, was observed to have increased as well.

Plate 3. Natural enemies of field insect pests

Palplopluera lucia

Plistospilota guineenis

Spider (unidentified)

Spider (unidentified)

Two bird species were recorded as severe pests. These were the Bronze Mannikin, *Lonchura cucullatus* and the Whydah, *Vidua macroura* which caused damage by sucking milky grain on panicles there by leaving empty grains at maturity.

3.5.6 Hard Dough-Maturity Stage

At this growth stage insect pest activities reduced considerably. Grain suckers such as *Aspavia* sp. *Oebalus* sp and *Nezara* sp were the only pests which were active. Their feeding activities resulted in empty grains. *Trichispa* sp were also found on fungal infested grains. The grasscutter, *Thryonomys* sp caused severe damage especially at Abodom and Abaam. Large flocks of the village weaver, *Ploceus* sp were the most serious pest at this stage. These were grain eaters which emptied grains on panicles.

Orb spiders, Praying mantids, Earwigs and the Dragonflies were the few natural enemies found at this stage. Other insects collected included *Apis* sp which were observed collecting pollen grains thereby acting as pollinators, *Dysdercus fasciatus* which may be sucking from the rice plant, *Calopteron recticulata* and *Hyprops chaceus*, beetles which may be feeding on pollen .

3.5.7 Discussion

Thirteen species of insect pest, fifteen natural enemies, three species of grain eaten birds and two species of rodents were recofed in the study. The insect pests caused the same damage to the rice plant at all the sites.

Odontotermis sp was the common subterranean insect pests that caused damage to the crop in the whole district. Their action appears to be limited to rainfed paddy fields (Breniere, 1983).

Afreh-Nuamah (1996) reported five species of stem borers on irrigated rice. These species included *Diopsis thoracica* (Diptera: Diopsidae), *Scirpohaga* sp

(Leidoptera: Pyralidae), *Maliarpha separatella* (Lepidopten: Pyralidae), *Chilo zacconis* (Lepidoptera: Pyralidae) and *Sesamia calamistis* (Lepidoptera:Noctuidae). In the present study *Diopsis thoracica* was the only and most important species occurring on upland rice ecology from seedling to the maturity stage of the crop on the field.

Grasshoppers (*C. longipennis, Turbida, Taphronota* sp *Acrida catoptroptergx, Z. variegatus*) were key defoliators identified in the study. On the other hand, important defoliators on irrigated rice were larvae of *Nymphula depunctalis, Spodoptera exempta, Diacresia* sp, *Nephotettix* sp and *Orseolia oryzivora.* Damage to the crop by case worms and whorl maggots are severe with standing water (Afreh-Nuamah, 1996). On both upland and irrigated rice, leaf feeders paly a minor role.

Campylenchia latipes were the common leaf suckers identified at all the study areas. Grain suckers identified in order of relative abundance were *Oebalus* sp, (average of 3 individuals per 10 hills) *Nezara* sp (average of 2 individuals per 10 hills), *Aspavia* sp (average of 2 individuals per 10 hills) and *Trichispa* sp (sporadic). Blay *et al* (2000) had listed *Stenocoris* sp, *Mirperus* sp, *Aspavia* sp, *Ritptortus* sp, *Nezara* sp and *Trichispa* sp as important rice bugs found on upland rice in northern Ghana.

The differences in the species of insect pests that occurred on irrigated rice and those identified in this study could be attributed to (i) differences in the production ecologies. In irrigated systems rice is grown on flooded land suitable for terrestrial and soil inhabiting insect pests. (ii) The continuous cropping of rice on the same piece of land season after season and the use of insecticides in the irrigated systems as opposed to shifting cultivation and non-use of insecticide in the study area.

Rodents identified during the study were *Rattus* and *Thryonomys* species. *Aryicanthis niloticus* and *Mastomys erythroleucus* had also been reported by

Breniere (1983). Village weavers, Whydah and Bronze mannikin were the common species of birds observed at all the study areas. Pande, (1994) had reported *Quelea quelea* and *Passer luteus* as principal seed-eating birds in Africa Spiders.

Dragonflies, Damselflies, Praying mantis and Lady beetles were the common natural enemies encountered at all the study sites. Afreh-Nuamah (1996) recorded *Tetrastichus* sp, *Telenomus cyrus,Trichomma* sp *Charops* sp, *Xanthopimpla* sp, *Cotesia* and *Braconid* wasps on irrigated rice. These Hymenopterans parasitized eggs and larvae of stemborers.

3.5.8 Population dynamics of Insect Pests and Natural Enemies

Diopsis thoracica occurred from seedling to hard-dough stage at all the study location. At ARS and Abaam there was a build-up of *Diopsis thoracica* populations between tillering and flowering stages and declined from soft-dought to hard-dough. At ARS-Okumaning for example the number of *Diopsis* increased from 11 individuals per 10 hills at the seedling stage to 34 individuals at the panicle stage (Fig.3). At Subi the *Diopsis* population dropped between tillering and flowering stages. The populations of grasshoppers (*Conocephalus longipennis, Turbida* sp, *Acrida* sp, *Taphronota* sp, *Zonocerus,* sp) varied at all the sampling locations. At ARS-Okumaning the number of grasshoppers increased from 5 individuals per 10 hills at the seedling stage to 13 individuals per 10 hills at the panicle stage. At Subi 10 individuals per 10 hills was recorded at the tillering stage. At Abaam 11 individuals per 10 hills was recorded at the panciles stage and at Pramkese, 9 individuals per 10 hills at tillering and soft-dough stages (Fig. 4). Grasshopper infestation at soft-dough stage or later do not usually result in any significant loss in yield (Nesbitt, 1997). As shown in (Fig. 5), the other insect pests (*C. latipes, Aspavia, Nezara, Oebalus)* species occurred from the tillering to the hard-dough stage. The populations of these stink bugs particulary *Oebalus pugnax* are affected by proximity and stage of nearby rice fields (Way, 1990; Nesbitt, 1997). More *Diopsis* per hill was recorded than was recorded for all the other insect pests. Large numbers were found at all the study locations. Elsewhere, the larvae cause serious damage (Breniere, 1983; Pande, 1994; Steele, 1970). The trends of population build-up of the natural enemies (*Palplopluera lucia, Plistospilota guineers, Orthetrum stemmate* and orb spiders) followed closely that of the insect pests at all the study locations (Fig. 6). This implies a density dependent relationship. These natural enemies generally maintain good levels of control (Claridge, 1990).

In all, twelve insect pest species from nine families were recorded. Of these *D. thoracica* represented about 65%, the grasshoppers (*C. longipennis, Turbida* sp, *Taphronota* sp, *Acrida* sp, *Catoptropteryx* sp, *Z. Variegatus)* 25% and the others (*C. latipes, Aspavia* sp, *Nezara* sp, *Oebalus* sp) 10% of the total number of pests sampled. Inspite of the large proportion of *D. thoracica* damage caused simply in terms of the number of deadheart on the field was very small at all the study areas. This situation may be attributed to the crop's compensational ability to produce new tillers and leaves to replace damaged ones (Breniere, 1983).

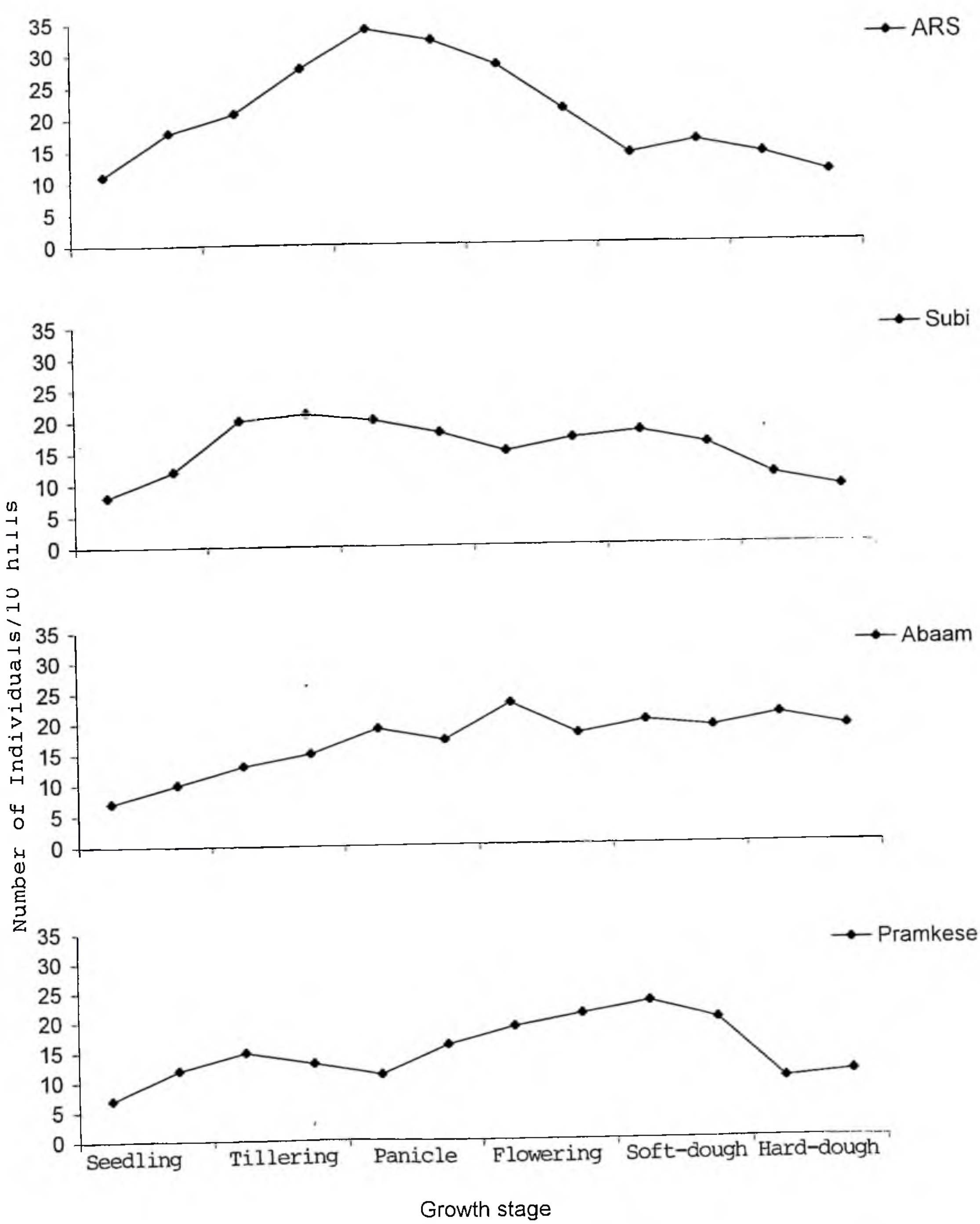


Figure 3: Population of *Diopsis thoracica* at different growth stages.

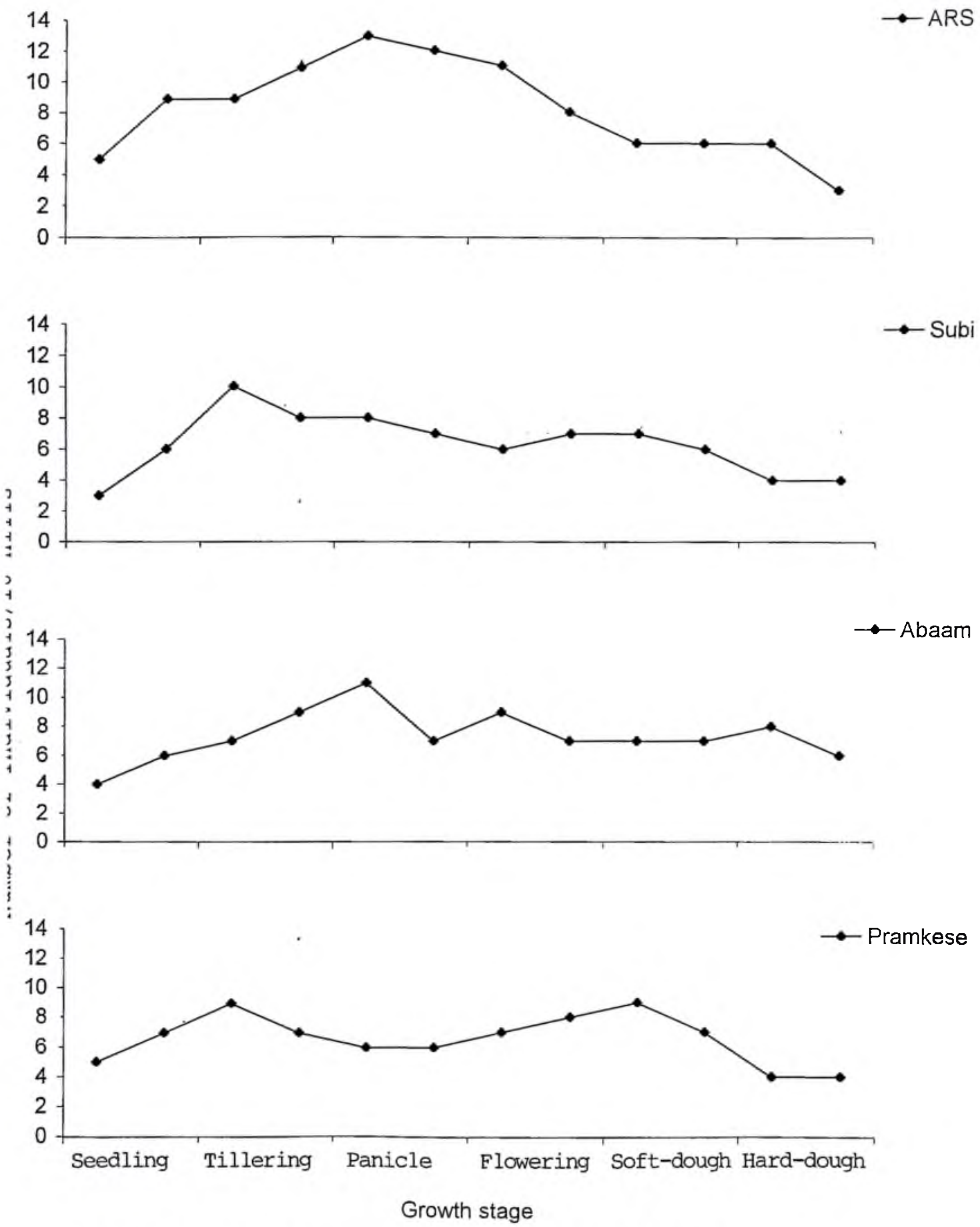
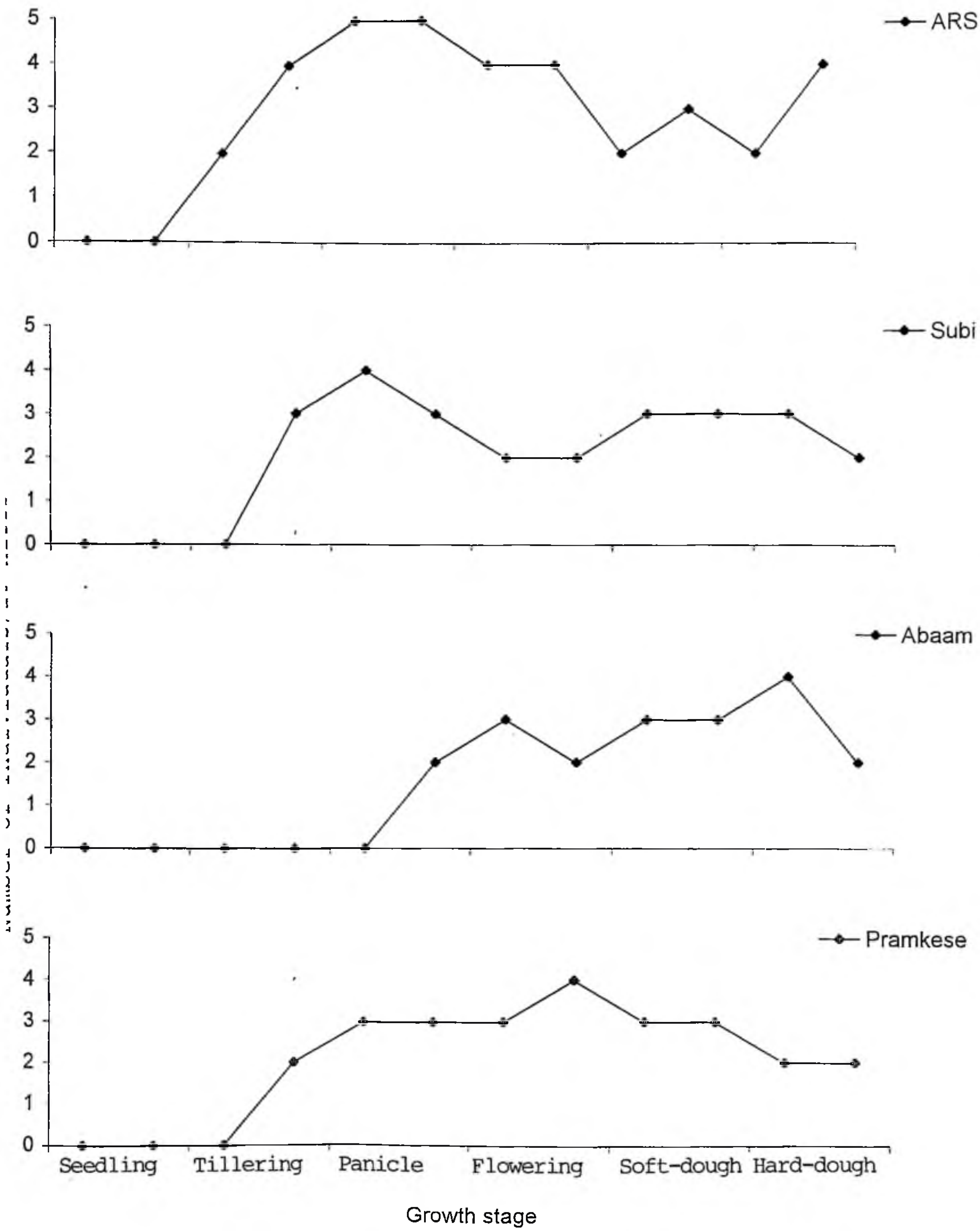


Figure 4: Population of Grasshoppers at different growth stages.



ure 5: Population of other insect pests (*C. latipes*, *Aspavia*, *Nezara*, *Oebalus*)at different growth stages.

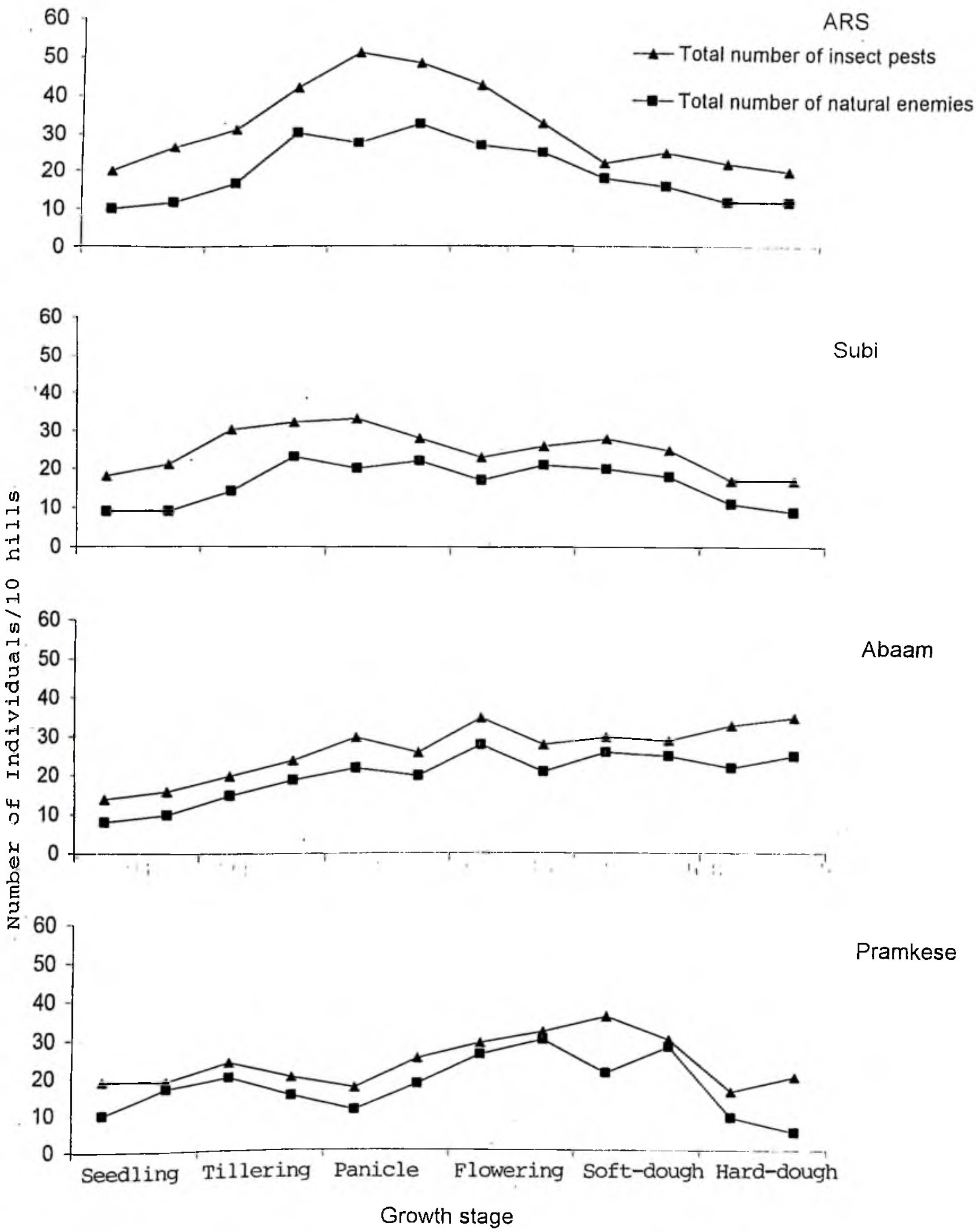


Figure 6: Population trends of insect pests and their natural enemies at different growth stages.

CHAPTER FOUR

INSECT FAUNA OF STORED PADDY

4.1 Introduction

Rice like other cereals is prone to attack by insects, fungi, mites, and rodents at all stages of storage (Grist and Lever, 1969).

The undamaged paddy is protected by the husk or hull from insect attack. But during harvesting many physical injury to the grain may provides entry points for insects. Infestation by stored product insects can produce different degrees of damage depending on the differences in physical properties or structure of grain such as hardness, grain size and presence or absence of hulls.

Rice may be stored in the unhusked state generally referred to as paddy or rough rice after removal of the husk, as hulled rice or after further processing, as milled rice (Steele, 1970).

Storage of paddy by farmers for food or seed is very often in bulk, in locally constructed structures which may be made from a range of materials. These are usually raised above ground, primarily to prevent damage by rodents and deterioration resulting from upward movement of moisture through the soil. Conical baskets constructed of woven grass made in varying sizes up to a capacity of 500 kg of grain are used in several areas (Hall, 1980). The most popular type of container used by small holder farmers in certain countries including Ghana are square or rectangular structures built of wood and divided into four or more compartments (Hall, 1980).

The most important factors affecting damage and deterioration of paddy and rice in storage are moisture content, relative humidity, temperature and storage period. High grain moisture content increases insect and fungal attack (Haines, 1991).

The present experiment was carried out to determine.

(i) Insect pests and natural enemies of stored paddy

(ii) The population dynamics of pests and natural enemies at different storage periods.

4.2 Materials and Methods

A wooden barn measuring 12m long by 3m wide and 3m high with slits for aeration was used for the storage of paddy. It was raised 1 metre from ground level and protected by rodent guards constructed for the storage of paddy (Plate 4). It was roofed with corrugated iron sheets and its floor was covered with straw mats. It was partitioned into three equal compartments with each measuring 4m x 3m x 2.5m high.

Paddy on panicles harvested by hand at the end of September 1990 at ARS – Okumaning were tied into bundles of one hundred panicles each for storage at an initial moisture content of 15%. The bundles were stacked into heaps. Each heap measured 1 metre square by 0.5 metre high (Plate 5). There were two similar heaps separated by a distance of 40cm. to allow movement in between heaps during sampling in each of the three compartments. In all there was a total of six heaps of stacked bundles of panicles of paddy.

Plate 4. Wooden storage structure

Plate 5. Stacked heap of paddy showing plastic sticky traps on top

4.3 Measurements of grain moisture, temperature and relative humidity

Grain moisture content was measured using a portable Grain Moisture tester operated on a six volts (6v) dry cell (Riceter J 301, Kett). Temperature and Relative Humidity in the barn were measured using a thermohydrograph (Medel KC10, 269F) placed in the middle of each compartment. The maximum and minimum temperatures and relative humidity were recorded at 9.00 am and 3 pm on each sampling occasion.

4.4 Sampling of insects

Yellow plastic sticky traps and paper card crevice traps were placed in each heap of paddy for the collection of insects on each sampling occasion.

One yellow sticky trap (Plate 5) mounted on a stick was placed 10cm above the surface of each heap of paddy to capture adult insects (Weston and Barley, 1998). The sticky traps were removed every two weeks. Insects trapped were collected using forceps and placed in 70% alcohol in a vial for preservation. Moths were kept in a vial containing no preservative to prevent discolourization of wings.

Crevice traps were constructed from two pieces of corrugated card board, measuring 6cm x 6cm, and glued together with sellotape. During the stacking of the bundles of panicle into a heap (section 4.2), nine of the crevice traps were placed 30cm horizontally from each other in the top layer. Another nine were placed 30cm horizontally from each other in the middle layer (25cm below the top layer). Nine were again placed 30cm horizontally from each other in the bottom layer (45cm below the top layer). The crevice traps were removed every two weeks to collect insects trapped. The used traps were not replaced

On each sampling occasion (every two weeks), each of the six heaps of paddy was divided into nine portions, one of which was picked for analysis and study. The bundles of the portion selected were carefully removed into a basket without disturbing the adjacent portions. The crevice traps found in the portions selected were removed. Insects trapped were collected into a jar containing 70% alcohol and preserved for identification.

During removal of the bundles, two each were selected from the top layer, middle layer (25cm below the top layer) and the bottom layer (45cm below the top layer). They were placed in transparent plastic bags and kept in the freezer for 12 hours in the laboratory to kill the insects contained in them. Sampling lasted for a total period of twenty weeks.

4.5 Insect identification

The preserved insects were identified using a taxomonic key and training manual by Haines, C.H. (1991) and the private collections of Mr. Ofosu (formerly a research officer at the Crop Research Institute based at Pokuase).

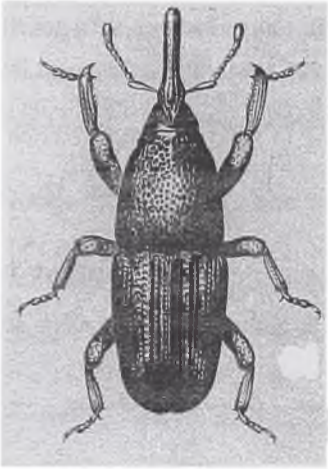
Bundles of paddy that were kept in the freezer were removed and panicles untied. Each untied bundle was examined for dead insect bodies using a hand lens in the laboratory. The dead insects were identified, counted and their numbers recorded. Students t test (P = 0.05) was used to test for significant differences between the mean number of insects collected.

4.6 Results and discussion

4.6.1 Insect pests

A total of five species of stored-product insect pests were collected in the study. This comprise four species of Coleoptera and one species of Lepidoptera (Table 7). The Angumois grain moth *Sitotroga cereallela* (Olivier) formed 51% of the insect pests sampled, the rice weevil, *Sitophilus* sp 42%. The red flour beetle, *Tribolium castaneum* (Herbst) 4% the dried fruit grain beetle, *Carpophilus dimidiatus* (F) 2% and the flat grain beetle, *Cryptolestes* sp 1% (plate 6). Hall

Plate 6. Insect pests of stored paddy

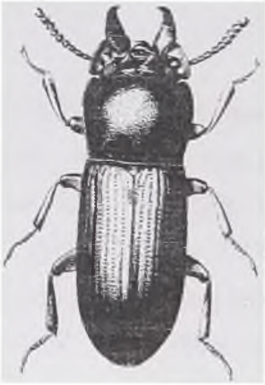


***Sitophilus* sp**

Tribolium castaneum

Cryptolestes ferrugineus

Rhyzopertha dominica



Gnatocorus cornutus

Source: Haines, 1991

(1980), Walker, (1992) and Nakakita (1998), had identified similar species, Boakye *et al* (unpublished) had listed *Sitophilus* sp *Rhyzopertha dominica, Sitotroga cereallela,* species of *Tribolium, Oryzaephilus, Cryptolestes, Ephestia* and *Corcyra cephalonica* as key pests of stored paddy in Ghana.

4.6.2 Population dynamics of insect pests

The fluctuation in the population of *Sitotroga cereallela* and *Sitophilus* sp were similar through out the study period (Fig. 7). *S. cereallela* increased from 120 individuals at the beginning of the sampling period to a peak of 220 individual by the 10th week before decreasing to 66 individuals at the end of the experiment. The number of *Sitophilus* sp also increased from 132 individual at the start of the sampling period to a peak of 220 individuals by the 10th week before decreasing to 31 individuals at the end of the experiment. Mean number of *S. cereallela* and *Sitophilus* sp, collected over the study period were 147.90 and 121.10, respectively. There was no significant difference between the mean numbers, t = 1,012, df = 16. The trend in the populations of these two insect pests was as a result of large fluctuations in relative humidity and diurnal temperature (Fig 9) in the storage barn. This development resulted in a decrease in grain moisture content (Fig. 10) from a level of 16% to 12%. As the grain moisture content decreased and the grains became dryer, feeding activity and hence multiplication of *S. cereallela* and *Sitophilus* sp. also decreased resulting in decreases in their populations.

In contrast, the fluctuation in the populations of *Tribolium castaneum, Cryptolestes* sp and *Carpophilus dimidiatus* showed much variability except for *Cryptolestes* sp which showed an increased over the last four weeks (Fig. 8). Mean number of *C. dimidiatus, Cryptolestes* sp and *T. castaneum* were 3.677, 5.44 and 12.671 respectively. There was significant difference between the mean number of *C. dimidiatus* and *T. castaneum.* T = 2.146, df = 16. There was however no significant difference between the means of *C. dimidiatus* and *Cryptolestes* sp t = 0.568, df = 16 and *T. castaneum* and *Cryptolestes* sp t = 1,546, df = 16. Again, the decrease in moisture content of grains accounted for the trend

Fig 7. Population dynamics of primary insect pests

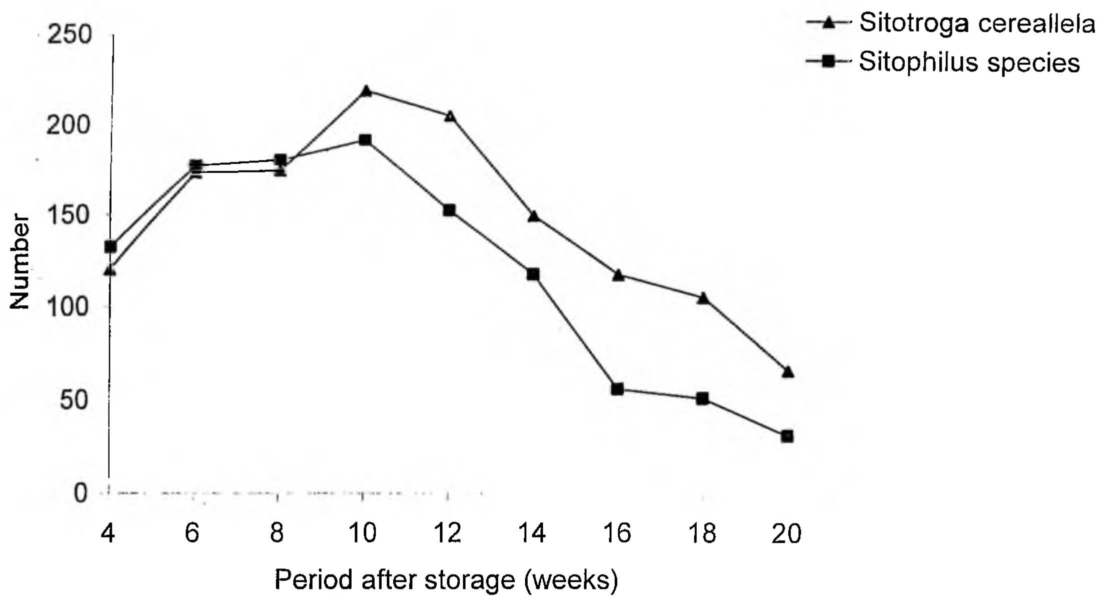


Fig 8. Population dynamics of secondary insect pests

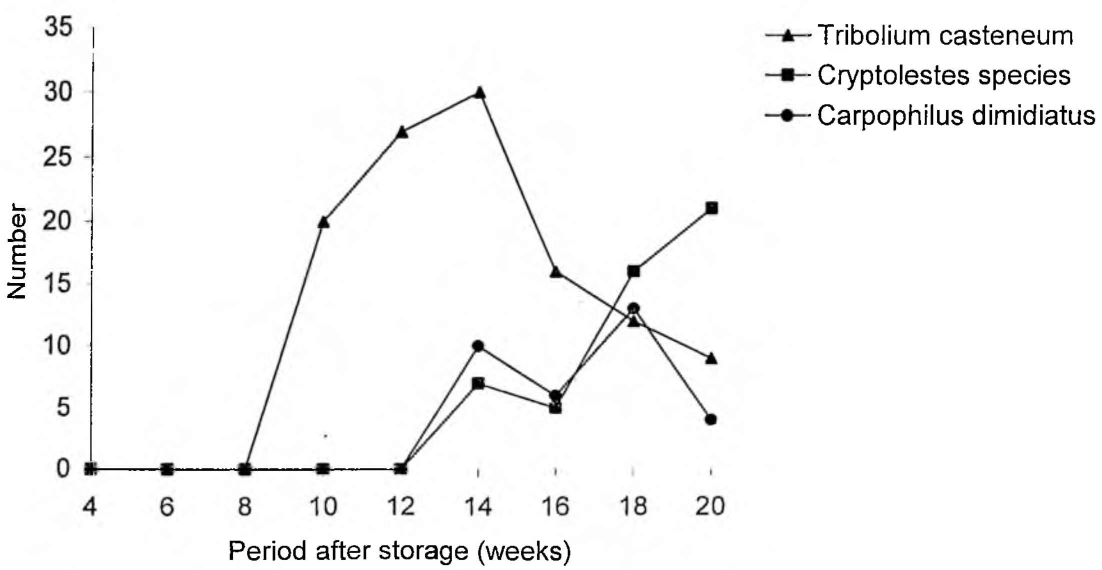


Fig 9. Mean temperature and relative humidity of storage environment

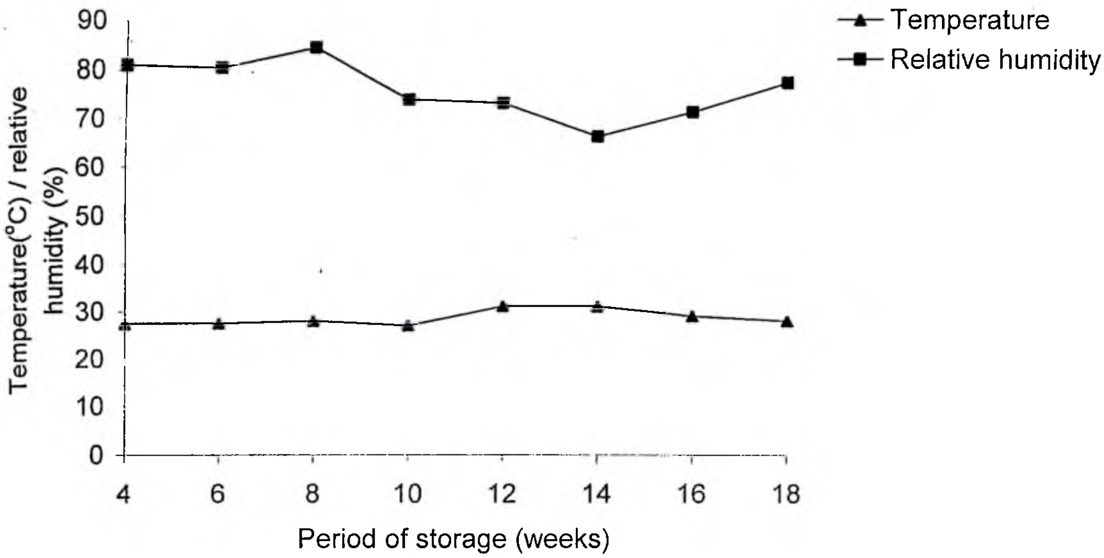
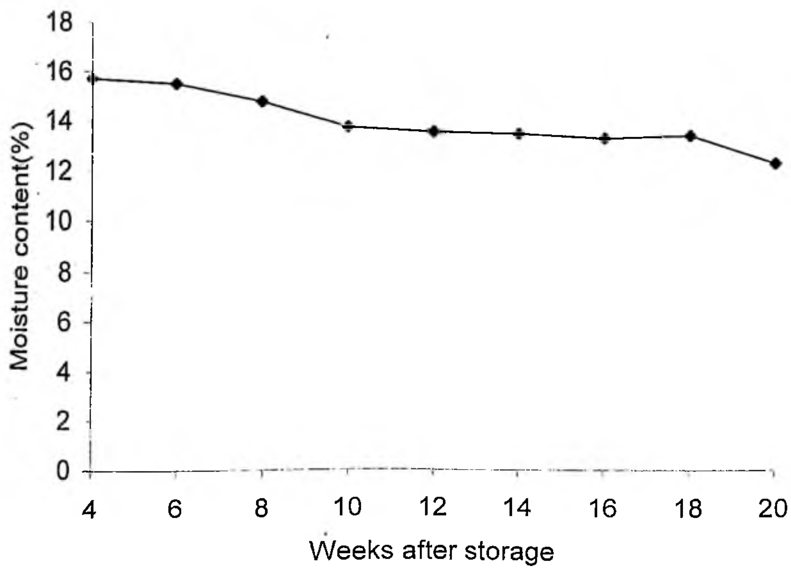


Fig 10. Grain moisture content



in the populations of these insect pests. As grain moisture content decreased and grains became dryer, feeding activities of the insect pests and their multiplication also decreased. Hagstrum (1994), Hall (1980), Haines (1991) and Steel (1970) had identified reduction in grain moisture content as a condition that affects insect pest population.

4.6.3 Natural enemies

Seven natural enemies were sampled over the study period (Table 8). Among them were four arthropod predators, one scavenger, a detritus feeder and one vertebrate predator. The arthropods included *Lyctocoris campestris* (Reuter), an anthocorid, spiders, pseudoscorpions and parasitic wasps. The predators fed on adult *S. cereallela* and larvae of other insect pests. Ants and fire brats operated as scavengers and detritus feeders, respectively. Pseudoscorpions, parasitic wasps, ants and fire brats are frequently encountered in stored products (Haines, 1991). Lizards, *Agama agama* were among predators observed preying on adult *S. cereallela.* In Ghana data on natural enemies on insect pest infestation of stored rice is very scanty. In Japan many natural enemies have already been identified. A parasitoid, *Anisopteromalus calandrae* and *Xylocolis flavipes*, a predator are especially noteworthy (Nakakita, 1998).

The contribution of lizards (*Agama agama)* as predators in reducing *S. cereallela* population was very encouraging. Monitoring their activity in the barn by recording the number of *S. cereallela* caught by sticky traps per sampling period from the twelveth week when they were first observed showed a 43% decline in their population. Their presence in paddy barns should be encouraged.

Table 7: Insect pest of stored paddy encountered

Species	Common name	Order	Family
Sitotroga cereallela (Olivier)	Angumois grain moth	Lepidoptera	Gelechiidae
Sitophilus sp	Rice weevil	Coleoptera	Curculionidae
Tribolium castaneum (Herbst)	Red flour beetles	Coleoptera	Tenebrionidae
Cryptolestes sp	Flat grain beetles	Coleoptera	Cucujidae
Carpophilus dimidiatus (F)	Dried fruit beetle	Coleoptera	Nitidulidae

Table 8: Natural enemies of stored paddy insects

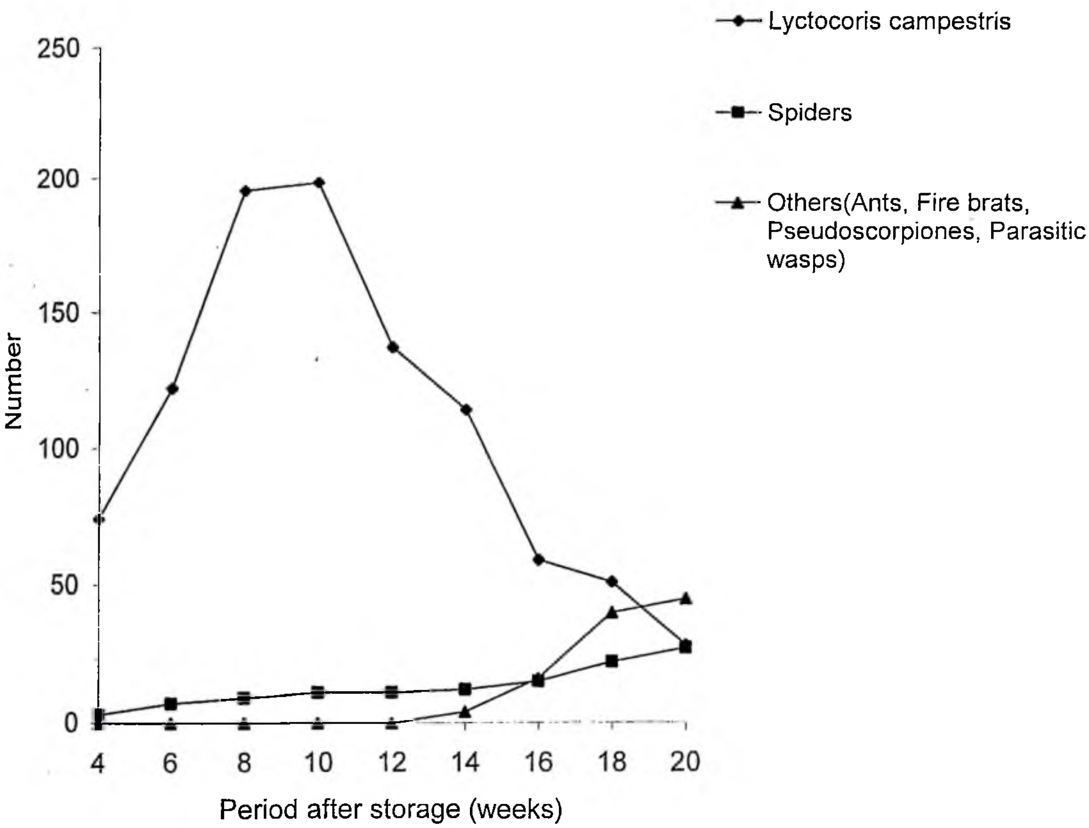
Natural Enemy	Order	Function
Lyctocoris campestris	Hemipter	Feed on eggs and larvae of *Sitotroga, Sitophilus* species
Spiders (unidentified)	Araneae	Feeds on adult *Sitotroga* sp
Pseudoscorpion (unidentified)	Araneae	Feeds on adult *sitotroga* sp
Parasitic wasp (unidentified)	Hymenoptera	Parasitize eggs of *Sitophilus* and *Sitotroga* species
Ants (unidentified)	Hymenoptera	Feed on dead insects (scavengers)
Fire brats (unidentified)	Thysanura	Detritus feeder
Agama agama	Lacertilia	Feeds on adult *Sitotroga*

4.6.4 Population dynamics of natural enemies

L. campestris was the most abundant natural enemy and the pattern of its population dynamics was similar to those of *S. cereallela* and *Sitoplilus* sp. The pattern for other natural enemies showed variation. Ants, fire brats, pseudoscropiones and parasitic wasps collectively showed steady increases in population from the forteenth week to the end of the study period. The pattern for spiders was, however, different, it increased from the start of the sampling period to the end of the experiment. (Fig. 11). The increases in the populations of these natural enemies which were recorded were due to the increases in insect pest populations over the same periods. This provided very favourable conditions for feeding and rapid multiplication of the natural enemies.

The study therefore confirmed the point that unthreshed paddy on panicles tends to suffer higher levels of insect pest, infestation, particularly of *S. cereallela* and *Sitophilus* sp, (MOFA, 1999). Infestation is also generally low when paddy is stored at low moisture content (<12%).

Fig 11. Population dynamics of natural enemies, scavengers and detritus feeders



CHAPTER FIVE

INSECT FAUNA OF MILLED RICE

5.1 Introduction

Milled rice (white rice) like other cereals is subject to attack by insects, fungi, mites and rats at all levels of storage. Indeed milled rice cannot be stored for long without deterioration especially in hot humid countries (Breniere, 1983).

Broken grain during milling may be the starting point for an infestation which may spread (Nakakita, 1998). Milled rice is almost invariably stored in bags stacked upon wooden pallet dunnage. This is to prevent the uptake of moisture resulting from upward movement of water vapour through the floor of the storage structure from the soil beneath.

Rice can also be stored parboiled; a process of soaking paddy in water for a period of one to three days and then subjecting it to steam at low pressure before drying and milling. Parboiled rice is less liable to insect attack and loss and leave better keeping qualities than white rice (Steele, 1970).

To enable farmers in the district to maximize profit through the sale of their produce, it is imperative that a good portion of paddy or milled rice be stored after harvest. The objective of this study was to determine the insect pest and natural enemies found in stored milled rice at different storage periods.

5.2 Materials and methods

Six new white woven polysacks (92cm x 58cm) were purchased from the market. Each of the polysacks was filled with 20 kg of white rice with moisture content of 12.8%. The sacks of rice were stored on pallet dunnage arranged in a row in a store room at ARS – Okumaning, (Plate 7).

Plate 7. Polysacks of milled rice on wooden pallet dunnage

5.3 Measurement of grain moisture, temperature and relative humidity

Grain moisture content was measured using a portable grain moisture tester operated on a 6v dry cell (Riceter J 301, Kett). Temperature and relative humidity in the store room was measured using a thermohydrograph placed between two polysacks. Maximum and minimum temperatures and relative humidity were recorded at 9.00 am and 3.00 pm respectively on each sampling day to determine the mean temperature and relative himidity.

5.4 Sampling of insects

Sampling of insects was started four weeks after filling the sacks with rice to give time for insects to multiply. Insects were sampled every two weeks. On each sampling occasion one of the polysacks containing rice was selected. The rice in it was poured out into a heap on a laboratory bench with a white top. The top of the heap was leveled and the bulk divided into four equal portions using a flat piece of cardboard (Walker, 1992).

Two of the four portions were combined, mixed, heaped and again divided into four portions. One of these portions (2.5kg) was used as a working sample. All the other portions were returned into the sack for resampling. The working sample was spread evenly on the bench. Using a hand lens, insects were picked with forceps from the grains into a vial containing 70% alcohol for preservation.

5.5 Insect identification

The preserved insects were identified using a taxonomic key and training manual by Haines, (1991) and the private collections of Mr. Ofosu (formerly of the Crop Research Institute, Pokuase). Insects were identified to the species level. Students t test (P = 0.05) was used to test for significant differences between the mean numbers of insects collected.

5.6 Results and discussion

Five insect pest species from four families were identified (Table 9). The most abundant insect pest was *Sitophilus* sp (Coleoptera: Curculionidae) which formed 63% of the total number of all the insect species collected. Their numbers increased steadily from the fourth week to the end of the experiment (Fig. 12). There is evidence from a number of countries including Ghana where attack by this species begins at least one month before harvest (Hall, 1980).

Other insect pests collected in increasing order of abundance were, *Gnatocerus maxillosus* (Coleoptera: Tenebrionidae), *Tribolium castaneum,* (Coleoptera: Tenebrionidae), *Rhyzopertha dominica* (Coleoptera: Bostrichidae) and *Carpophilus dimidiatus*. Nakakita (1998), Walker (1992), Breniere (1983) and Steel (1970) listed similar insects on stored rice. Gu *et al* (1996) also identified these same insects as the main pest species of stored rice in South China. The population of both *C. dimidiatus* and *R. dominica* increased sharply up to the tenth week and then increased steadily till the end of the sampling period. The pattern of increase in the population of *T. castaneum* and *G. maxillosus* were similar, increasing sharply over the entire period (Fig. 13). The mean number of *C. dimidiatus, R. dominica, T. castaneum* and *G. maxillosus,* were 72.57, 42.84, 19.27 and 9.27 respectively. There were significant differences between the mean numbers of *C. dimidiatus* and *G. maxillosus*, t = 4.81, df = 14, and *T. castanemum,* t = 4.24, df = 14. There was, however, no significant difference between the mean number of *C. dimidiatus* and *R. dominica,* t = 1.61, df = 14. Significant difference existed between the mean number of *R. dominica.*

Fig 12. Population dynamics of Sitophilus species

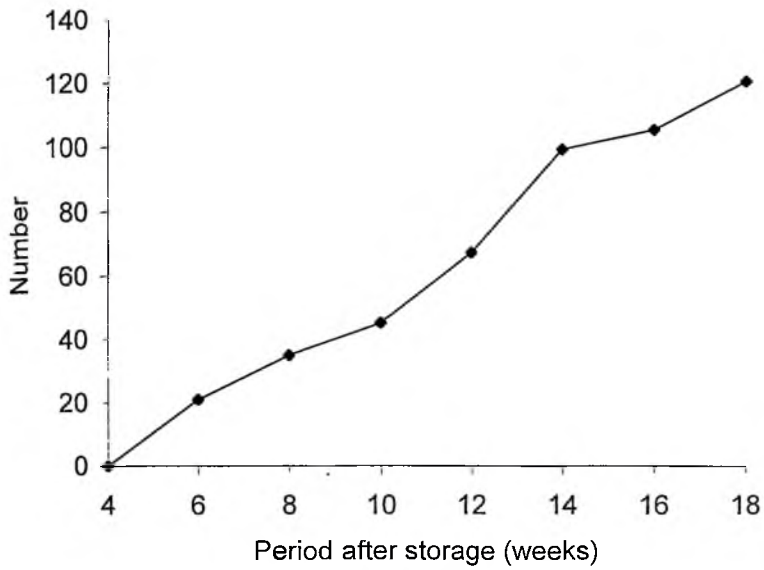
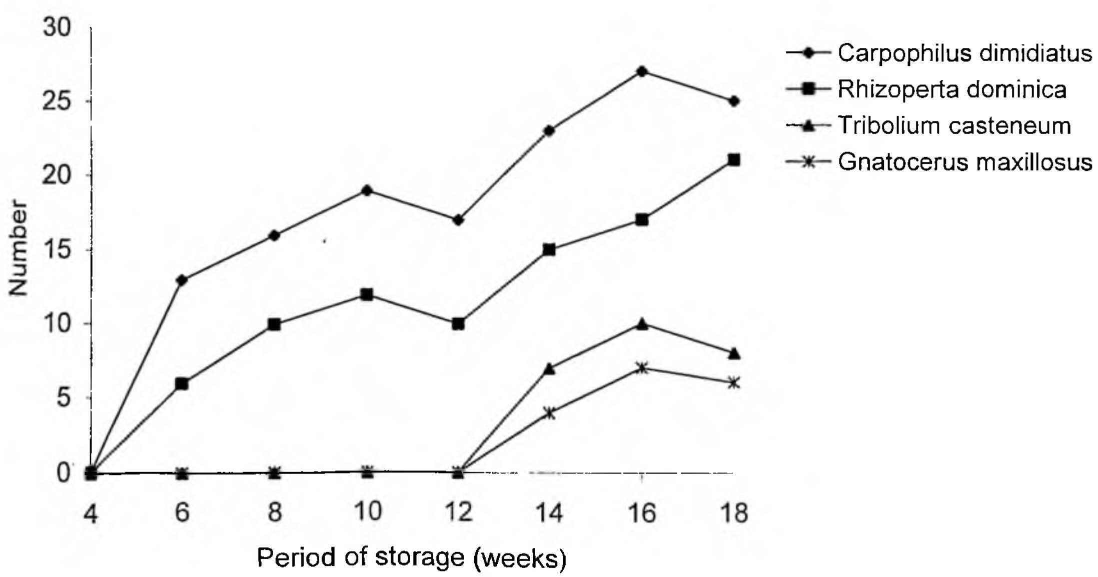


Fig 13. Population dynamics of secondary insect pests



and *T. castaneum*, t = 2.96, df = 14, but there was no significant difference between the mean number of *T. castaneun* and *G. maxillosus*, t = 0.53, df =14. Damage to grains by insect pests was conspicuous and manifested by the presence of hollowed grains and powder in the bulk. Thus it was observed from the study that farmers in the district cannot store milled rice for extended periods under uncontrolled storage atmospheric conditions. Increase in relative humidity resulted in increases in grain moisture content (Fig 14). Increased grain moisture content and temperature (Fig 15) provided favourable conditions for the rapid multiplication of insects. All insects living on stored grains depend on grain moisture for development. Hagstrum (1994) identified increased grain moisture content, temperature and the amount of broken grian as factors responsible for rapid growth in insect populations.

Table 9. Insect pests found on stored white rice at ARS- Okuamaning

Common name	Species	Order	Family
Rice weevil	*Sitophilus* sp	Coleoptera	Curculionidae
Dried fruit beetle	*Carpophilus dimidiatus* (F)	Coleoptera	Nitidulidae
Lesser grain borer	*Rhyzopertha dominica* (Fab)	Coleoptera	Bonstrichidae
Red flour beetle	*Tribolium castaneum* (Herbst)	Coleoptera	Tenebrionidae
Slender-horned flour beetle	*Gnatocerus maxillosus* (Fab)	Coleoptera	Tenebrionidae

Table 10. Natural enemies found on stored white rice at ARS- Okuamaning

Natural enemy	Order	Function
Earwig (unidentified)	Dermaptera	Predator
Ants (unidentified)	Hymenoptera	Scavenger
Liposcelis sp	Psocidae	Detritus feeder
Wasps (unidentified)	Hymenoptera	Parasitoid
Spiders (unidenfitied)	Arachnida	Predator

Fig 14. Grain moisture content

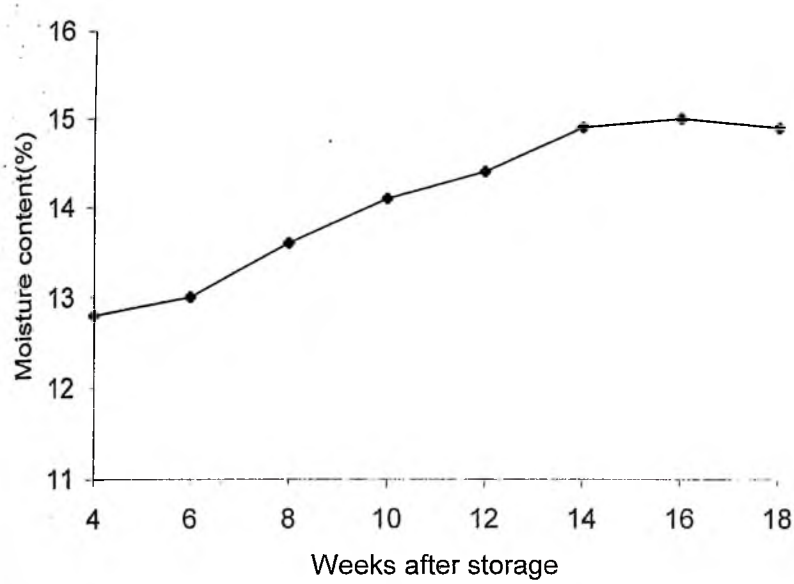
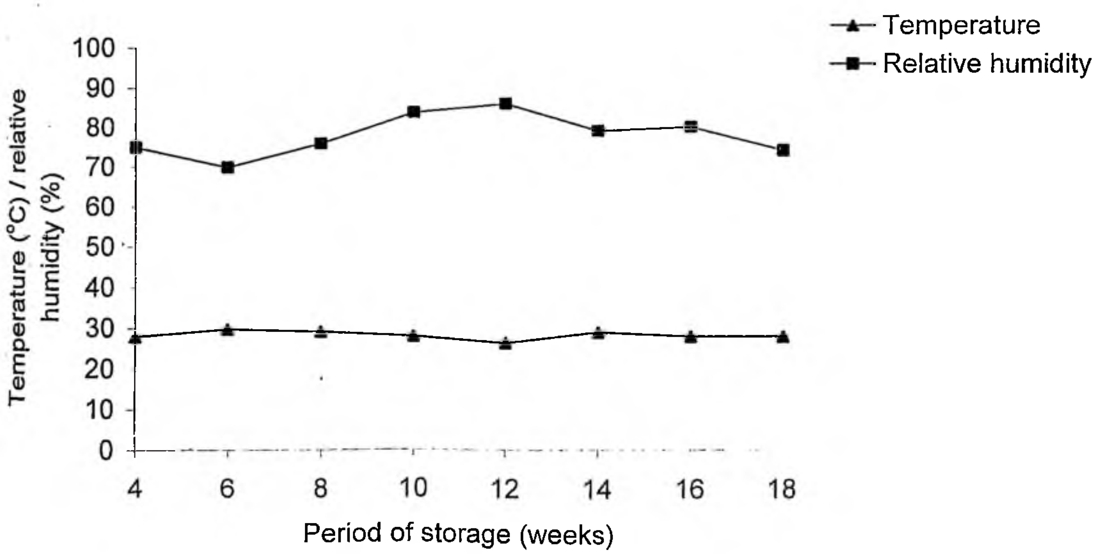


Fig 15. Mean temperature and relative humidity of storage environment



The main natural enemies collected were parasitic wasps. They parasitized eggs of *Sitophilus* sp. Earwigs, ants and *Liposcelis* sp were detritus feeders encountered. Klieh and Pike (1995) reported *Liposcelis* spp infestation in Indonesia and India. Spiders were observed preying on *Sitophilus* sp on the outside and in between polysacks of grain on pallet dunnage.

CHAPTER SIX

Conclusions and recommendations

A range of insect species (pests and natural enemies) were recorded on all the growth stages of production, storage and processing of upland rice in the district.

Odontotermis sp were the subterranean insect pests identified. *Diopsis thoracica* was the most important stem borer which occurred at all the growth stages on the field. *Conocephalus longipennis*, *Turbida* sp, *Acrida* sp, *Taphronota* sp, *Catoptropteryx* sp, and *Zonocerus variegates* were the key defoliators. Grain suckers identified included *Oebalus* sp, *Nezara* sp, *Aspavia* sp and *Trichispa* sp.

Inspite of the presence of these insect pests in the rice ecosystem in the study areas, the pest situation in the district was not very alarming. This situation may be attributed to growing of paddy under shifting cultivation by farmers and the activities of the many natural enemies present in the rice ecosystem. Important natural enemies identified included *Anaxipha* sp, *Palplopluera Lucia*, Orthetrum *stemmate* and *Enallagma* sp preyed on eggs and adult *Diopsis*. *Agriocnemis* sp, *Menochilus sexmaculates*, *Harmonia octomaculata* and *Euborella* sp which preyed on small larvae and eggs of ants. Parasitoids identified were *Argrophylax* sp and *Temelucha* which parasitized stem borer larvae. *Plistopilota guineenis*, *Chlidonoptera chorpardi*, *Phidippus* sp and Orb spiders preyed on nymphs and adult grasshoppers and *Diopsis* sp.

However, the risk of severe pest problem and the potential for losses at all stages in the future cannot be ruled out since rice cultivation is being intensified in the district and the availability of land for shifting cultivation may be affected. In view of the growing global awareness of the hazards of continuous use of insecticides to the environment, the users and the disruption of natural balance between pests and their natural enemies, the following cultural practices are recommended:

(i) Early and synchronized planting, good weed management and the destruction of stubbles after harvest to get rid of diapausing larvae of *Diopsis*. Heaping cleared weeds to provide shelter and humid conditions near the ground to encourage increased activities of ground living predators are recommended for the control of *Diopsis*.

(ii) New rice varieties that are resistant to stem borers among other stress resistant/tolerant characteristics (WARDA, 1999) be introduced to farmers in the district so as to optimize rice production. Bearing in mind other qualities preferred by farmers.

(iii) Early planting and using early maturing varieties and the judicious use of fertilizers could be effective in keeping populations of defoliators and leaf suckers low.

(iv) Rice bugs such as species of *Aspavia, Nezara* and *Oebalus* could be controlled by eliminating from the farm and surrounding areas grassy weeds (alternative host plants) (Blay *et al* 2000).

(v) Integrated Crop and Pest Management (ICPM) through Farmers Field School (FFS) should be organized for the farmers in the district to enable them adapt new knowledge to solve local pest problems under local condition and enhancement of rice production.

The greatest challenge was damage caused by birds. At all the study areas farmers adopted manual scaring as a means of minimizing damage. Bird scaring using catapult from dusk to down was the common method.

Insect pests that fed on paddy and milled rice in storage were *Sitotroga cereallela*, *Sitophilus* sp, *Tribolium casteneum*, *Cryptolestes* sp and *Carpophilus dimidiatus*. Natural enemies encountered were *Lyctocoris campestris*, Pseudoscorpiones and Parastic wasp. These natural enemies fed or parasitized eggs and larvae of *Sitotroga* and *Sitophilus* species respectively. The quality of milled rice is severely affected by the presence of body fragments of insect pests. The feeding activities of these insect pests also produce large quantities of waste flour in the bulk. In view of these it is recommended that farmers in the district store rice in the form of paddy instead of milled rice.

REFERENCES

Afreh-Nuamah, K (1996) Report on IPM Farmers Firld Schools in Ghana, F.A.O. Accra 90 pp.

Bland, R. G. and Jaques, II. E. (1978). How to know the insects, W. C. Brown Comp. Pub. Dubuque, lowa 409 pp.

Blay, E., cudjoe, A.R., and Braun, M., (ed) (2000) Handbook of Crop Protection recommendations in Ghana: An IPM Approach Vol. 1: Cereals and Pulses, MOFA, Pokuase, 76 pp.

Bor, S. L. (1979) Rice Production and Utilization. Avi. Pub. Comp. Ltd. West Port. pp 3-26.

Breniere, J. (1983) The principal insect pests of rice in West Africa and their control WARDA Monrovia, pp. 87.

Buddenhagen, I. W. and Persley, G. J. (1978) Rice in Africa Academic Press London. pp 175-179.

Claridge, M. F. (1990) Variation in pest and natural enemy populations relevant to brown plant hopper control strategies. Pest Management in Rice. Elsevier Appl. Sc. Pub. Ltd. 143-154.

Dickson, K. B. and Benneh, G. (1983). A New Geography of Ghana Longman Gp. Ltd. England pp. 17-34.

Donald, T. B. and Richard, E. W. (1970) A Field Guide to the Insects of America North of Mexico. Houghton Mifflin Comp. Boston 404 pp.

Dutta, A. C. (1990) Botany for Degree Students Oxford University Press. Delhi. pp. 778-779.

Farmer, B. H. (1982) Green Revolution? Techology and change in Rice-growing Area of Tamil Nadu and Sri Landa. Macmillan press Ltd. London p. 429.

Grist, D. H. (1983) Rice, 5th Ed. Longman London and New York pp. 311-314.

Grist, D.H. and Lever, R.J. (1969). Pest of Rice. Longmans, Green and Co. Ltd. London 520 pp.

Gu. D. Gao, X., Tao, F., Qiu, Y., Huang, Z., Hu, M., Jiaug, Z. (1996) Insect pests and Diseases in Rice and Application of pesticides. Guangdong Science and Tech. Press pp 30-75.

Hagstrum, D. W. (1994) Field monitoring and prediction of stored-grain insects populations. Postharvest News, Inf. 5, 39-45.

Hall, D. W. (1980) Handling and storage of food grains in tropical and sub tropical areas, F.A.O. of UN Rome pp. 160-171

Haines, C.H. (ed) (1991) Insects and arachnids of tropical stored products; their biology and identification Natural Resources Institute, Kent. UK. pp 246.

Hollay, M.E., Smith, C.M. and Robinson, J.F. (1987) Structure and formation of feeding sheaths of rice stink bug (Heteroptera: Pentatomidae) on rice grains and their association with fungi, Ann, Entomol, Soc. Am. 80: 212-216.

Juo, A.S.R. and Lowe, J. A. (1985) The wetland and rice in Sub Sahara Africa. IITA – Ibadan pp. 141-149.

Kenmore, P. E., Cariono, F.O., Perez, C.A., Dyck, V.A. and Gutierrez, P. A., (1984). Population regulation of rice brown plant hopper (*Nilaparvata lugens* Stal) within rice fields in the Philippines. Journal of plant protection in the tropic, 1:1937.

Klieh, U and Pike, V. (1995) Economic assessment of psocid infestations in rice storage. Tropical Science 35 (3): 280-289.

Mikkelsen, D. S. and Evatt, N. S. (1966) Soils and fertilizers in Rice in the United States: Varieties and production, Agric. Res. Serv. US. Dep. Agric. Handb. No. 289.

Ministry of Food and Agriculture (MOFA) (1999) Task Force Report on Proposals for improving Rice Production technology and quality in Ghana. 45 pp

Nakakita, H. (1998) How to protect rice from Insect pests. Farming Japan 32-6: 20-24

Nesbitt, H. J. (ed) (1997) Rice production in Cambodia. Int. Rice Research Inst. Cambodia, Manila (Philippines) pp 84-91.

Onwueme, I. C. and Sinha, T. D. (1991) Field crop Production in tropical Africa, Michael Health Ltd. Reigate Survey Rit 29 EL. pp 200-214.

Pande, H. K. (1994) Improved upland rice farming system. F.A.O. of UN Rome. pp 75-93.

Pearman, N.M. (1990) Area wide rice field rat control by small scale land owners in S.E. Asia through the co-ordinated application of flocoumafen block bait. Pest Management in rice. Elsevier Appl. Sc. Pub. Ltd. Pp 430-439.

Purseglove, J.W. (1985) Tropical crops. Monocotyledons. Longman Gp Ltd. England pp. 198-191.

Serle, W. and Morel, G. (1992) Birds of West Africa. William Collins and Sons & Co. Ltd. London pp. 239-261.

Shepard. B. M. (1990) Integrated management in rice. Present status and future prospects in Southeast Asia. Pest Management in Rice. Elsevier Appl. Sc. Pub. Ltd. pp 258-268.

Shepard, B.M., Barrown, A.T. and Litsinger, J.A. (1991). Friends of the rice farmer. Helpful insects, spiders and pathogens. IRRI, Philippines pp. 127.

Simmonds, N.W. (1984) Evolution of crop plants. Longman Gp. Ltd. England pp. 98-103.

Smith, W.C. (1995) Crop Production: Evolution, history and technology. John Wiley and Sons. Inc. New York. pp 220-267.

Smith, C.M., Bryarat, J.L., Linscombe, D.S., and Robinson, J.E. (1986) Insect pest of rice in Lousiana Louis. Agric. Exp. Stat. Bull. 774.

Steele, B. (ed) (1970) Pans Manual No. 3 Pest control in rice. Ministry of Overseas Development, London 270 pp.

Surajit, K.D. (1981) Principles and practice of rice production. John Wiley and Sons, New York pp. 420-440.

Van Emden, H.F. (1996) Pest control, Cambridge University Press, London. pp 57-72.

Walker, D.J. (1992) Food storage manual. World Food Programme (WFP) Rome. 180 pp.

Way, M.O. (1990) Insect pest management in rice in the United States. Pest Management in Rice. Elsevier Appl. Sc. Pub. Ltd London and New York pp 181-189.

West Africa Rice Development Association (WARDA) (1999) New rice for Africa, Mbe. Cote d'Ivoire. 20 pp.

West Africa Rice Development Association (WARDA) (1998). WARDA Annual Report 1997 Mbe, Cote d'Ivoire. pp 19-26.

Weston, P. A. and Baraey, J. J. (1998) Comparison of three trap types for monitoring insect populations in stored grains. J. Econ. Ent. 91 (6) pp. 1449-1457