

EVALUATION OF COMPARATIVE EFFICACY OF SOME  
PLANT POWDERS FOR THE CONTROL OF  
CALLOSOBRUCHUS MACULATUS (F.) (COLEOPTERA:  
BRUCHIDAE) ON STORED COWPEA

By

ALPHONSUS MBONU OPARAEKE  
(BSc. (Hons.) Agriculture, UNISOK). 1985

A thesis submitted to the Post Graduate School, Ahmadu Bello University, Zaria, in partial fulfillment of the requirement for the Degree of Master of Science in Crop Protection.

DEPARTMENT OF CROP PROTECTION  
FACULTY OF AGRICULTURE  
AHMADU BELLO UNIVERSITY, ZARIA  
NIGERIA

AUGUST, 1997.

DECLARATION

I hereby declare that this thesis has been written by me and that it is a record of my research work. It has not been presented previously in any form for a higher degree award.

*Alphonsus Mbonu Oparaeke*

.....  
ALPHONSUS MBONU OPARAEKE

Date: ..... 28-5-98 .....

The above declaration is confirmed.

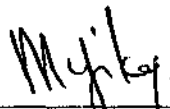
*M. C. Dike*

.....  
DR. M. C. DIKE  
(Major Supervisor)

Date: ..... 28/5/98 .....

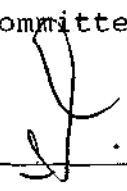
## CERTIFICATION

This thesis entitled "EVALUATION OF COMPARATIVE EFFICACY OF SOME PLANT POWDERS FOR THE CONTROL OF CALLOSBRUCHUS MACULATUS (FAB.) (COLEOPTERA: BRUCHIDAE) IN STORED COWPEA" by Alphonsus Mbonu Oparaeke meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

  
 \_\_\_\_\_  
 Dr. M. C. Dike  
 Chairman,  
 Supervisory Committee

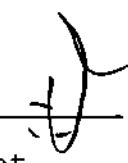
Date: \_\_\_\_\_

28/5/98

  
 \_\_\_\_\_  
 Dr. I. Onu  
 Member, Supervisory Committee

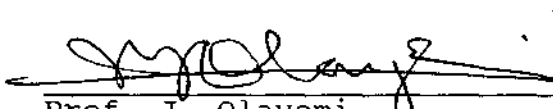
Date: \_\_\_\_\_

1/6/58

  
 \_\_\_\_\_  
 Dr. I. Onu  
 Head of Department

Date: \_\_\_\_\_

1/6/58

  
 \_\_\_\_\_  
 Prof. J. Olayemi  
 Dean, Post graduate School  
 Ahmadu Bello University, Zaria.

Date: \_\_\_\_\_

24/9/98

**DEDICATION**

This work is dedicated to my late parents, Mr. Augustine Amadi Oparaeke and Mrs. Janet Uwaoma Oparaeke for their contributions in my academic successes. May they rest in perfect peace, Amen.

To my wife, Millie and my children, Ifeyinwa, Chukwuemeka, Nnamdi and Obiora for their patience and understanding. May God bless them in Jesus Name, Amen

A. M. OPARAEKE

## ACKNOWLEDGEMENTS

"If the hand of God is not in a house, the builder is labouring in vain". For this reason, therefore, I wish to thank God primarily, for the able way He protected and guided me throughout the duration of my study. To Him be the glory for ever, Amen.

I wish to express my profound gratitude to my Major Supervisor, Dr. M. C. Dike, for his invaluable contributions, guidance and constructive criticisms throughout the period of this research. I am also grateful to Dr. I. Onu, a member of the supervisory committee, for his advice and contribution towards the success of this work.

My appreciation goes to S. Akibu, A. Adakole, Mrs. M.O. Okeke, Rex Eleazu (Crop Protection Department); Sis. Joy Ubani (Legumes/Oilseed Programme) and the entire library staff, IAR.

I am indebted to PEDUNE and the National Coordinator for Nigeria, Prof. A. M. Emechebe for the Scholarship award and financial support. I am grateful to my employer, the Institute for Agric. Research and Crop Protection Department, A.B.U., Zaria, for providing me the opportunity to undertake this study.

Finally, my sincere thanks go to Dr. J. N. Okoye and many other individuals not mentioned due to lack of space for their moral support and to the Computer Programmer, Tina Okere, for a job well done.

A. M. OPARAEKE

## ABSTRACT

Laboratory trials were conducted at the Department of Crop Protection, Institute for Agricultural Research, Ahmadu Bello University, Samaru- Zaria, to evaluate the efficacy of various plant powders (Neem Seeds and Leaves, Garlic bulbs, Orange peels, African Curry leaves, Onion leaves, African bush tea leaves, Lemon grass stem powders) and a conventional insecticide, Actellic dust, for the control of cowpea weevil, Callosobruchus maculatus (Fab.).

Plant powders were applied at three concentrations: 2.5, 5.0, 10.0g per 100g cowpea seed and actellic dust was applied at 1.0, 2.0 and 3.0g per 100g cowpea seed.

The criteria used for assessing the efficacy of these products included, mortality at 24 hours, 48 hours and seven days post treatments; oviposition rates; progeny development ( $F_1$ ,  $F_2$ ,  $F_3$ ), percentage cowpea damage and weight losses; seed viability, grain quality and taste, after three months of storage.

The results showed that there was high mortality within 24 hours on cowpea treated with actellic dust at the highest level (3.0g w\w) which had 100 percent adult weevil mortality. African curry leaf powder (ACLP) at all three levels; Neem seed powder (NSP), Eucalyptus leaf powder (ELP); and Garlic Bulb powder (GBP) caused more than 45 percent mortality of bruchid at the highest level (10.0g w\w) within the same period.

The critical period of adult weevils activity after emergence is within 48 hours. During this period, however, some of the plant extracts (such as NSP, ACLP, GBP, ELP, Lemon grass stem powder (LGSP) and Orange peel powder (OPP) recorded between 55.0 and 98.34 percent adult weevil mortality at the various treatment levels as compared with no deaths in the control.

NSP achieved 100 percent inhibition of F<sub>1</sub> at the highest treatment level (10.0g w/w) compared with Actellic dust which recorded less than 75 percent progeny inhibition at the highest level. Other plant materials which had more than 50 percent inhibition of progeny development at the highest concentration included GBP, ELP, ACLP and NLP.

The percentage damage and weight loss were least on cowpea treated with NSP at all treatment levels; followed by actellic dust and ACLP at similar levels. Actellic dust and powders of NSP, ACLP, NLP and GBP, LGSP, ELP, ABTP (African bush tea powder), OPP deterred oviposition and larval development.

Seed viability and grain quality were largely unaffected by the treatments when compared with the control. Generally, in all the parameters studied, these plant products and Actellic dust showed better performances as their treatment levels increased, suggesting that higher doses should be used (except for actellic dust) to establish the optimum concentration of powders that would be more effective than the ones used in the present trials.

**CONTENTS**

Title Page .....	i
Declaration .....	ii
Certification.....	iii
Dedication .....	iv
Acknowledgements .....	v
Abstract .....	vi
Contents .....	viii
Tables.....	xii
Appendices .....	xiv

**CHAPTER ONE**

INTRODUCTION .....	1
--------------------	---

**CHAPTER TWO**

LITERATURE REVIEW .....	6
2.1 COWPEA.....	6
2.1.1 Origin and Nutritional Importance.....	6
2.1.2 Factors Affecting Cowpea Storage in Nigeria .....	7
2.2.0 Insect Pests and Damage Losses in the Store .....	9
2.2.1 Taxonomy and Morphology of <u>Callosobruchus maculatus</u> (F.) (Coleoptera:Bruchidae).....	10

2.2.2	Life cycle .....	11
2.3.0	Control of <u>C. maculatus</u> in storage.....	15
2.3.1	Chemical Control .....	15
2.3.2	Use of plant materials .....	18
2.3.3	Neem Products .....	20
2.3.3.1	Economic Importance .....	21
2.3.3.2	Chemical Constituents and Insecticidal Properties .....	21
2.3.4	Eucalyptus Products .....	26
2.3.4.1	Economic Importance of Eucalyptus ....	27
2.3.4.2	Chemical Constituents and Insecticidal Properties .....	28
2.3.5	Lemon-Grass Products .....	30
2.3.5.1	Economic Importance of Lemon Grass ...	30
2.3.5.2	Chemical Constituents and Insecticidal Properties of lemon grass .....	31
2.3.6	Garlic and Onion Products .....	32
2.3.6.1	Economic Importance of Garlic & Onion..	33
2.3.6.2	Chemical Constituents and Insecticidal Properties .....	34
2.3.7	Other Natural Products as Grain Protectants ..	35

### CHAPTER THREE

3.0	MATERIALS AND METHODS .....	37
3.1.0	Evaluation of plant powders & actellic dust for control of <u>C. maculatus</u> on stored cowpea...	39

3.1.1	Effect of plant powders and actellic dust on Mortality of adult <u>C. maculatus</u> .....	40
3.1.2	Effect of plant powders and actellic dust on oviposition and progeny emergence of <u>C. maculatus</u> .....	40
3.1.3	Effect of plant powders and actellic dust on infestation levels and loss in weight of stored cowpea due to <u>C. maculatus</u> after 12 weeks ....	41
3.1.4	Effect of plant powders and actellic dust on grain viability after 12 weeks of storage ...	41
3.1.5	Effect of plant powders and actellic dust on grain quality after 12 weeks of storage .....	42

#### CHAPTER FOUR

4.0	RESULTS AND DISCUSSIONS .....	43
4.1	Effect of plant powders and actellic dust on mortality of adult <u>C. maculatus</u> .....	43
4.2	Effect of plant powders and actellic dust on oviposition of <u>C. maculatus</u> at 15 days post treatment .....	50
4.3	Effect of plant powders and actellic dust on adult emergence of <u>C. maculatus</u> .....	54
4.4	Effect of plant powders and actellic dust on percentage damage of cowpea by <u>C. maculatus</u> at 12 weeks post treatment .....	60

4.5	Effect of plant powders and actellic dust on percentage weight loss caused by <u>C. maculatus</u> on cowpea stored for 12 weeks.....	63
4.6	Effect of plant powders and actellic dust on the viability of treated cowpea grains stored for 12 weeks .....	66
4.7	Effect of plant powders and actellic dust on quality of cowpea grains after 12 weeks of storage.....	68

#### CHAPTER FIVE

SUMMARY AND CONCLUSION .....	73
REFERENCES.....	80
APPENDICES .....	98

## TABLES

1.	Effect of plant powders and actellic dust on percentage mortality of <u>C. maculatus</u> at 24 hours post treatment .....	44
2.	Effect of plant powders and actellic dust on percentage mortality of <u>C. maculatus</u> at 48 hours post treatment .....	46
3.	Effect of plant powders and actellic dust on percentage mortality of <u>C. maculatus</u> at seven days post treatment .....	48
4.	Effect of plant powders and actellic dust on oviposition of <u>C. maculatus</u> at 15 days post treatment .....	51
5.	Effect of plant powders and actellic dust on percentage F <sub>1</sub> progeny of <u>C. maculatus</u> at four weeks post treatment .....	55
6.	Effect of plant powders and actellic dust on F <sub>2</sub> progeny of <u>C. maculatus</u> at eight weeks post treatment .....	56
7.	Effect of plant powders and actellic dust on F <sub>3</sub> progeny of <u>C. maculatus</u> at 12 weeks post treatment .....	57
8.	Effect of plant powders and actellic dust on percentage grain damage caused by <u>C. maculatus</u> at 12 weeks post treatment .....	61

9.	Effect of plant powders and actellic dust on percentage weight loss of cowpea seeds at 12 weeks post treatment .....	64
10.	Effect of plant powders and actellic dust on percentage viability of cowpea seeds at 12 weeks post treatment .....	67
11.	Effect of plant powders and actellic dust on quality (colour, texture and palatability) of cowpea grains after 12 weeks of storage .....	69

## A P P E N D I C E S

Appendix	Page
1. Analysis of variance for the effect of various plant powders and actellic dust on mortality of adult <u>C. maculatus</u> Fab. within 24 hours post treatment .....	98
2. Analysis of variance for the effect of various plant powders and actellic dust on mortality of adult <u>C. maculatus</u> within 48 hours post treatment .....	98
3. Analysis of variance for the effect of various plant powders and actellic dust on mortality of adult <u>C. maculatus</u> within seven days post treatment .....	99
4. Analysis of variance for the effect of various plant powders and actellic dust on oviposition of adult <u>C. maculatus</u> at 15 days post treatment ..	99
5. Analysis of variance for the effect of various plant powders and actellic dust on F <sub>1</sub> progeny development of <u>C. maculatus</u> at four weeks post treatment .....	100
6. Analysis of variance for the effect of various plant powders and actellic dust on F <sub>2</sub> progeny development of <u>C. maculatus</u> at eight weeks post treatment .....	100
7. Analysis of variance for the effect of various plant powders and actellic dust on F <sub>3</sub> progeny development of <u>C. maculatus</u> at twelve weeks post treatment .....	101
8. Analysis of variance for the effect of various plant powders and actellic dust on Percentage cowpea damage by <u>C. maculatus</u> after twelve weeks of treatment .....	101
9. Analysis of variance for the effect of various plant powders and actellic dust on percentage loss in weight of grains after twelve weeks of treatment .....	102
10. Analysis of variance for the effect of various plant powders and actellic dust on grains viability after twelve weeks of treatment .....	102

11.	Correlation matrix of parameters for the effect of various plant powders and actellic dust on <u>C. maculatus</u> control .....	103
12.	Determination of moisture contents of various plant materials used in the trials .....	104
13.	Average monthly laboratory temperatures and Relative Humidity from January - December 1995 and 1996 .....	105

## CHAPTER ONE

### 1.0 INTRODUCTION

Cowpea, *Vigna unguiculata* (L.) Walp (Leguminosae) is a tropical, herbaceous annual, known by various names in different parts of the world including the black-eye pea, black-eyed bean, china pea, kaffir-pea and marble pea (Purseglove, 1974). In Nigeria, its name is as varied as the diverse ethnic groups inhabiting it. For instance, the crop is known by the Hausas, Ibos and Yorubas as 'Wake', 'Agwa' and 'Ewa' respectively.

Cowpea is an important, cheap, protein source in the diet of most people in the third world countries. In Nigeria, cowpea is more relished than other grains and in the Western part of the country alone, it constitutes up to 60 percent protein uptake (Rachie and Rawal, 1976). The grain is consumed in various forms either cooked as porridge or in combination with rice, yam or it is ground and fried as cake (akara) or steamed as "moi-moi". The green seeds and immature pods are eaten fresh or may be frozen or canned, but are less important in Africa because of shorter storage life. The dry seeds are much more appreciated for their long storage life, good nutritional properties (crude protein, 23-25%; carbohydrate, 55-60%; fibre 3.9%; ash 3.6% and fat 1.3%), relative ease of storage, and preparation for consumption. The herbage is useful as green manure, cover crop and as fodder (Harawa) when dry for dry season feeding of livestock

in the savanna region of Nigeria.

Cowpea is extensively grown in Brazil, India, the Carribeans, South east Asia and the United States of America. The major areas of production in West Africa include Nigeria, Niger, Burkina Faso, Senegal and Sierra Leone. World production of Cowpea is estimated at 2.50 million tonnes cultivated on about 7.7 million hectares of land (Olufade, 1987). Africa and Nigeria produced 95% and 61% respectively of world's output (Rachie and Roberts, 1974), estimated at about 800,000 tonnes (Raheja, 1986). The current output figure for 1989/90 cropping season in Nigeria was about 1.4 million tonnes (Anonymous, 1990). The main production areas include Bauchi, Borno, Jigawa, Kaduna, Kano, Katsina and Sokoto States, all within the Guinea and Sudan savannas, north of Latitude 10°N. However, some appreciable quantities are also produced in the rain forest belts, particularly in the South West. The bulk of cowpea is grown by small scale farmers who sometimes interplant it with cereals such as maize, millet or guinea corn. Average yield in peasant holdings is about 200 kilogrammes per hectare (Ayedokun, 1988) and in commercial farms 700-1200 kilogrammes per hectare. However, about 1.5-2.0 tonnes/ha in controlled trials on farmers' fields using improved technologies have been achieved (IITA, 1984).

Cowpea yield is low because of several constraints of which damage by numerous pests and diseases, are the major

ones. Almost all parts of the plant are attacked by various insect pests and more than 85 insect species have been found to cause damage to cowpea cultivated at the Institute for Agricultural Research Farm in Samaru (Booker, 1965). Some of these field pests include Maruca vitrata Fab., Thrips, Pod sucking bugs, Aphids and Oothea spp.

In storage, Cowpea is attacked by a number of insect pests. Some of these are field to store pests, notably, Callosobruchus maculatus (F.) and C. chinensis (L.), Bruchidius atrolineatus also causes tremendous damage to ripening pods on the field but its attack fizzles out during the early stages in the store (Booth, 1976). C. rhodesianus (Pic) found in South Africa causes damage in localized areas (Giga and Smith, 1987). In Nigeria, cowpea losses to beetles have been estimated at 2.44 million tonnes for 1981/82 and 3.67 million tonnes in 1984/85 (Ivbijaro, 1983a).

In the past, control measures adopted by various governments and research institutes were centred around storage structures such as barns, granaries (Rumbus) and silos. Thereafter, insecticides were introduced but these sooner than later created such problems as pest resistance, pest resurgence as well as environmental degradation (Saxena, 1987) resulting in world-wide call to minimize their usage and to develop less hazardous pest control measures (Luna and House, 1990). Fortunately, nature has offered us a profusion of plants for use in crop protection. These plant materials

have been used by small holder farmers in Nigeria to protect stored products from insect pest damage for a long time. Although, some of these plant species (neem, lemon grass, citrus peels, chillies, Hyptis sp. etc) may have given some measure of control against C. maculatus based on individual material used, yet, no attempt has so far been made to specifically screen and coordinate their efficacies in a single experiment.

**The objectives of this study include:-**

- i. To evaluate the efficacy of powders obtained from these plant species and compare them with each other and against a known synthetic storage pesticide on the mortality of C. maculatus.
- ii To ascertain appropriate levels of plant powders required for effective control of C. maculatus on stored cowpea.

**II JUSTIFICATION OF THE PRESENT STUDY**

Increasing reports of food poisoning due to chemicals employed to preserve some food items particularly during the period of scarcity, coupled with current high cost of these chemicals in Nigeria have made it expedient to search for alternative but effective control measures for storage pests. Between May and August, cowpea purchased from most markets around Zaria are treated with kerosine, Aldrin dust or other chemicals which are not strictly recommended for protection of cowpea for consumption. The effect is that after cooking, these chemicals impart objectionable odour and taste to the

meal and may be remotely toxic to human beings.

The fact is that, the traders and farmers are aware of the vital need to preserve their produce for the period of scarcity but probably are ignorant of the damage they may cause to mankind by using unauthorized chemicals for grain storage. The use of natural plant products as bio-pesticides to control pests of stored produce has become necessary as an alternative to synthetic insecticides which though effective, are expensive and may be toxic to mammals and cause pollution to the environment.

## CHAPTER TWO

## 2.0 LITERATURE REVIEW

2.1 COWPEA

## 2.1.1. ORIGIN AND NUTRITIONAL IMPORTANCE

Cowpea, Vigna unguiculata (L) Walp (Fam:Leguminosae) is speculated to have originated in Africa. Faris (1965), led by evidence of the presence of wild progenitors of cowpea in West and Central Africa suggested that the region was the nucleus of cowpea domestication. In the West African sub-region, Nigeria was postulated as centre of origin of cowpea because of the existence and widespread distribution of different varieties and wild-prototypes. Ezedinma (1961), stated that by the nation-wide practices and prejudices associated with the culture and utilization of the crop in Nigeria, its African centre of origin is not in doubt.

Cowpea is an important food source in Nigeria and the third world countries because of its high protein content (23-25%). Mean per capita consumption of dry beans in Africa (31.40kg) is higher than in the Latin America (13.30kg). Dry bean consumption can be classified as low (13kg/yr. or 36g/day), medium (25kg/yr or 68g/day) and high (50kg/yr. or 137g/day) (Krista, et al. 1990).

The nutritional importance of cowpea in the diet is determined by the percentage of recommended dietary allowance (RDA) for nutrients that are satisfied by beans of various levels. Krista et al. (1990) reported that in countries where

bean consumption is high, dry grains provide more than one-half of the dietary protein and up to one-quarter of the energy requirements. Olayide (1972) reported that a minimum daily adult requirement of 58.91g available protein per head per day is needed in Nigeria out of which, over 60 percent is supplied by cowpea (Rachie and Rawal, 1976). Cowpea is also an important source of iron and provides over 100 percent of the RDA for this mineral. However, it is the storage life of the dry seeds rather than their nutritional advantages that makes the grains the most consumed bean product in developing countries (Anon., 1968).

#### **2.1.2. FACTORS AFFECTING COWPEA STORAGE IN NIGERIA**

In the recent past, agricultural production efforts have been directed primarily to increasing crop yields through the use of improved crop production technology without a corresponding attention being focused on effective storage of such crops. In effect, substantial amounts of different agricultural produce are lost yearly to storage insect pests.

**The main factors affecting cowpea in storage include:-**

##### **i. HIGH MOISTURE CONTENT**

Cowpea seeds should be adequately dried in the sun or mechanically dried before storage. Morris and Wood (1956) reported that high moisture beans produced more carbon dioxide and used more oxygen, indicating elevated

cell metabolism. Cowpea below 10 percent seed moisture content (M.C.) at 25°C could be stored for two years, whereas storage above 13 percent M.C. at 25°C for six months resulted in reduced ability to cook. In addition, high moisture beans also darken more rapidly during storage (Burr et al., 1968), whereas with lower M. C., there is less colour change (Morris and Wood, 1956).

ii **POOR STORAGE FACILITIES**

The condition of storage structures contributes immensely in the preservation of cowpea grains. Poorly constructed storage structures or those with cracks and leaking roofs encourage insect pest build up and subsequent damage to grains in the store.

iii **MECHANICAL DAMAGE DURING HARVEST**

Cracked or damaged cowpea grains are readily a veritable source of insect pest infestation during storage, and do not store well due to the exposure of the seed endosperm to pests.

iv **TRANSIT PROBLEMS**

Cowpea losses during transportation due to pest attack is of economic importance in Nigeria. Storage methods adopted by many local farmers during transportation to distant markets are inadequate. A considerable quantity of cowpea grains are transported from the major production centres in the north of Nigeria to the southern markets by rail or road throughout the year. It

has been reported that about 50% of the grains arriving in the South may be damaged by beetles (Anon. 1962).

#### 2.2.0 INSECT PESTS AND DAMAGE LOSSES IN THE STORE

About 15 percent of world's total crop is lost during cultivation as a result of insect pest attack and a further 20 percent is lost during post-harvest storage, with losses in tropical countries being greater than the world average (Hill and Waller, 1990).

Cornes (1964), reported that over 200 species of insects are found on different crops stored in Nigeria. Losses in stored cereals in northern Nigeria alone range from 4-10 percent due to storage pests out of 3.8 million tonnes of sorghum, 1.8 million tonnes of millet and 320,000 tonnes of maize produced (Adesiyun, 1973). This represents an annual loss of about 200,000 tonnes of grains worth about five million naira.

Cowpea is lost to many pests both in the field and during storage, hence, its potential yield is seldom achieved. Raheja (1976) estimated yield losses in cowpea plots of above 80 percent in Nigeria. In storage, *C. maculatus* (F). has been found to be the major insect pest of cowpea (Southgate et al, 1957; Bottimer, 1968; Taylor, 1970).

Up to 37 percent holed beans in the northern Nigeria have been reported and a total loss estimated at about 24,000 tonnes per annum have been recorded in Nigeria (Caswell,

1968). Damage is confined to the larval stage and one individual larva could cause a three to five percent weight loss in a cowpea seed (Booker, 1967). Seed germination was also adversely affected when three or more bruchid fed in a seed (Ofuya, 1987).

**2.2.1 Taxonomy and Morphology of Callosobruchus maculatus (Fab.) (Coleoptera:Bruchidae).**

Callosobruchus maculatus is a major field-to-store pest of cowpea in the tropics and sub-tropics (Southgate et al. 1957, Bottimer, 1968; Taylor, 1970). The insect has been known by the following synonyms in the past:-

Bruchus maculatus F. 1775  
B. quadrimaculatus F. 1792  
B. ornatus Boh., 1829  
B. vicinus Gylh.; 1833  
B. ambiguus Gylh., 1839  
B. sinuatus Fhs., 1839  
C. maculatus (Fab) Brid. 1929

(Southgate et al. 1957 and Bottimer, 1968).

The insect is a small beetle about 2.5 to 5.5 mm long, and has a pair of parallel ridges on the ventral side of each hind femur which bears a tooth near the apical end. The compact body is covered with short hairs while the elytra cover the whole abdomen except the last abdominal tergum (pygidium). The antennae are serrated and the eyes strongly

emerged along the inner edge where the antennae are inserted. The males are brown and females are darker with black and white marks on the elytra. C. maculatus is a more elongate species than C. chinensis with the posterior part of the abdomen not covered by the elytra, and it is more definitely spotted (Hill and Waller, 1990).

### 2.2.2 LIFE CYCLE

The bean weevil, Callosobruchus maculatus completes its life cycle between 20 and 30 days depending on the temperature, relative humidity and nature of the sub-stratum of its host (William, 1980).

For instance, one cycle is completed between 18-21 days at 20°C-27°C; 25-27 days at 33°C and 30-35 days at 19°C-24°C. Each female lays up to 100 eggs singly (Dobie et al., 1984). On average, one cycle is completed monthly under favourable conditions with 4-5 larval instars found inside the seeds (Booker, 1967; Tun, 1979). The adult weevil is short-lived (between 7 and 14 days but usually up to 12 days under optimum conditions) and they do not feed at all but continue to lay eggs.

The eggs are small, whitish, dome-shaped with oval, flat bases and are glued to the surface of the host which may be smooth or rough. The eggs hatch in six days into the first instar larvae, with pronounced appendages and spined thoracic plates which are used for seed penetration. Caswell (1960)

reported that, during hatching the scarabaeiform larvae bite through the bases of the eggs to the testa and cotyledons of the seed within three days after oviposition and the first and second larval stages take about seven days. However, Tun (1979) observed a slight variation in the developmental periods of C. maculatus from egg to pre-emergence of the adult and concluded that egg incubation takes between 3-5 days, first and second larval instars 3-9 days; while the third and fourth larval instars take 1-3 days.

The larvae are partly or wholly apodous, blind and whitish-yellow in colour. As development progresses inside the seed kernel, the larva makes a chamber separated from the outside by the seed coat from which the adult weevil forces its way out, leaving a characteristic round hole usually found on seeds. After 7-12 days (in some cases 20 days) in the seed, the larvae pupate just under the testa. The pupa is exarate. Emergence takes approximately 4 to 5 weeks and about 6-7 generations may occur in a year (Hill and Waller, 1990).

Seed size and compactness affect the rate of bruchid development. Large seeded varieties are more susceptible to oviposition due to their larger surface area which also, offer more nutrients and ensure larger number of developing adult progeny than small seeded ones (Booker, 1967; Nwanze and Horber, 1975). The developing female requires more food than the male counterpart. Credland and Dick (1987) established a positive relationship between the amount of food available to

each developing larvae and the mean weight of adults emerging from the seeds, as well as the size of the adult weevil.

Other factors influencing the length of developmental period and the time of emergence of C. maculatus from the infested seeds include seed resistance. An extension of developmental period of C. maculatus in the resistant cowpea varieties compared to the susceptible varieties has been observed (El-Sawaf 1956). On susceptible cowpea varieties, adult emergence starts within 22 days at 27°C (Redden, 1983). For resistant cowpea varieties, both the initiation emergence and the time to peak adult emergence was found to be 5-10 days (Redden, 1983).

C. maculatus exhibits a phased dimorphism, with two distinct forms of adults of each sex differing not only in morphology but also in physiology, chemical composition of the body, behaviour and response to environmental factors (Osuji, 1985). The two adult forms are the flight or distributive (Active) form and the non-flight form (Utida 1954). The "active" (flight) form is strongly marked with a white pygidium, flies readily, lives longer and the female lays fewer eggs which may not be viable (Southgate et al., 1957; Caswell, 1960). The "active" males and females usually live for more than one month; their flights occurring through the 24 hour cycle with peak flight activity just before dusk (Taylor and Agbaje, 1974). Temperature is the most important factor influencing flight activity.

Studies conducted on mature cowpea in the field indicated that the 'active' females were more abundant than the normal (non flight) females, and constitute between 26 and 71 percent of all adults on early and late crops, respectively (Taylor, 1970). Taylor and Aludo (1974) also reported that "active" females were more abundant (1.5 times) than the normal females for the early season crop and 4.5-5.0 times more than the normal females for the late season crop. Factors influencing the production of 'active' forms include:- larval crowding (Utida 1954, 1965; Sano 1967; Caswell 1960; Taylor 1974; Taylor and Agbaje 1974), high temperature (Sano, 1967; Taylor and Agbaje 1974; Utida, 1954; Tun, 1979), low moisture content of the seeds (Caswell, 1960; Utida, 1969) and continuous darkness/light (Taylor and Agbaje, 1974), the latter factor apparently not convincing. Genetic factors may also play an important role in the production of "active" forms (Caswell, 1960; Utida, 1972).

Reports indicate that significant physiological and reproductive differences exist between the 'active' and normal forms in both males and females (Caswell, 1960; Utida, 1965; 1968; 1972). The two forms differ in their body weight, water content and the quantity/nature of their fats (Utida and Takahashi, 1958). Tun (1979) dissected the "active" and "normal" forms of females and males of C. maculatus just after emergence and observed that the normal females have two well developed ovaries with some eggs in the calyx while the males

have well developed testes. However, the reproductive systems of "active" males and females were found to be underdeveloped.

This phenomenon of 'active' form facilitates the species' dispersal as the population builds up during storage (Taylor 1974). The build up of bruchid population in the store and its ability to fly readily and live longer facilitate the dispersal of the insect (Utida, 1972) to other fields and storage sites (Taylor and Agbaje 1974; Taylor and Aludo, 1974).

### 2.3.0 CONTROL OF C. MACULATUS IN STORAGE

C. maculatus is controlled effectively in the store using the following methods:-

#### 2.3.1 CHEMICAL CONTROL

A number of insecticides have been found to be effective against cowpea weevils, C. maculatus in storage (Booth, 1976; Howe, 1978; Egwuatu, 1987). Some of these insecticides include, among others fumigants: (Aluminium phosphide (phostoxin); carbon tetrachloride; methyl bromide, ethylene dibromide); dusts (malathion, permethrin or pirimiphos-methyl, iodofenphos), lindane (Gamma-HCH), and DDT). These insecticides used in the control of insect pests of stored products should be toxic to the insects at very low doses and should also have low mammalian toxicity. A dose of 2000 mg/kg

body weight or above for acute oral toxicity to rat is considered desirable (Handmarsh et al., 1978).

Fumigation of stored products has been found to be effective against pest damage. Fumigants are effective in controlling the eggs and larvae inside the seed, and adult insects without any residue (Abivardi, 1977; Singh and Jackai, 1985). Aluminium phosphide at the rate of 4 tablets per tonne of cowpea grains stored for 15 months in silos was very effective in eradicating C. maculatus (Caswell, 1980). Tun (1979), reported that Aluminium phosphide when used in plastic bags to store grains has adequate persistence.

Methyl - bromide and carbon tetra chloride have also been used to control pests of cowpea in storage. Bastos and Aguiar (1971) and Bastos (1974), reported the effectiveness of methyl -bromide when applied to cowpea seeds 5-6 days, 10-11 and 2-21 days after C. maculatus have laid their eggs on the seeds. Kranz et al. (1977) found a mixture of carbon tetra-chloride and ethylene dichloride at 1:3 ratio to be effective against C. maculatus in silos. However, the use of carbon tetrachloride as a fumigant in food storage has been banned world-wide due to its carcinogenic effects on man.

Pirimiphos-methyl has been widely used in the control of insect pests of stored products. Taylor and Evans (1980) reported that application of diluted formulation of pirimiphos-methyl and permethrin at the rate of between 2.5 and 10.0 mg/kg of pigeon peas, and haricot beans controlled

adult C. chinensis effectively. Caswell and Akibu (1980) found that cowpea seeds treated with pirimiphos-methyl at a concentration of 15 parts per million (ppm) were protected for 12 months against C. maculatus. Similarly, Tun (1979) observed that cowpea seeds dressed with pirimiphos-methyl emulsion were also protected from latent infestation due to the bruchids. Sowunmi and Fetuga (1982) reported a sharp degradation of residue of pirimiphos-methyl applied to cowpea grains within the first three months of application and further degradation to about half life-span by the end of the sixth month and fairly constant up to the 12th month of storage. This was attributed to the hot humid conditions of the tropics which require higher initial deposits for protection against insect infestation.

Malathion dust also has been observed to be effective against bruchids in stored cowpea (Chipeta and Roberts, 1974). Rahman and Yadav (1985) reported the efficacy of delta-methrin dust at 3 ppm concentration which retarded the development of eggs, larvae and pupae of C. maculatus and C. chinensis in stored cowpea for six months and posited that the dust formulation was superior in terms of toxicity than the solution. Earlier, DDT and malathion dusts were found (Yadav, 1973) to be highly efficacious on treated seeds of chick pea, pigeon pea, green gram, black-gram, lentil and grass pea against the pulse beetles, but at a higher dose of 40 ppm. However, lindane and carbaryl, even at 50 ppm were less

effective in controlling the pulse beetles, due to the development of resistance by the pests, which has been reported world-wide (Dyte and Blackman, 1970).

Some plant compounds, for example, 2,5-Dihydroxymethyl-3,4-dihydroxy-pyrrolidine (DMDP) and an analogue of B-fructo-Furanose, have been reported to be toxic to the larvae of cowpea beetle when incorporated into an artificial diet at more than 0.03 percent level (Evans *et al.*, 1985).

### 2.3.2 USE OF PLANT MATERIALS.

Plant products have been used for many years (Jacobson, 1958; 1975) amongst the peasant farmers to control insect pests of stored produce but their importance was initially limited and over looked. Many of these plant species with repellent, antifeedant and insecticidal properties have been recognized long before the industrial revolutions of the 1920's and 1940's. However, only a few products such as nicotine, rotenone and pyrethrum were used to some extent to control storage pests and in green houses (Schmutterer, 1981). Nicotine from tobacco plant, Nicotiana tabacum and N. rustica was first used as an insecticide in 1963 (Matsumura, 1975). Rotenone, a poisonous insecticide is derived from some leguminous plants such as Derris elliptica from Malaysia; D. malaccensis from East India and Lonchocarpus utilis and L. uruca from South America (Matsumura, 1975). Pyrethrin, the world's foremost natural insecticide, is extracted from dried

flowers of Chrysanthemum cinerariofolium. Olaifa et al., (1987) reported that pyrethrin and its synthetic counterpart pyrethroid, possess a unique combination of useful properties such as safety, flushing action, fast knock down, repellency, bio-degradability, broad spectrum of activity and minimal ability to induce insect resistance which have made them the most widely used all round domestic insecticides available today.

Various spices have been found to be effective in controlling storage insect pests of crops. For instance, black pepper, Piper nigrum (L.), a source of piperine which has insecticidal properties was reported to be effective in controlling rice weevils (Su, 1977). Similarly, Piper guineense was found to be potent in controlling cowpea bruchid, C. maculatus (Ivbijaro and Agbaje, 1986; Olaifa and Erhun, 1988). Reports on Capsicum spp, a safe and promising source of naturally occurring insecticide for the control of stored produce pests have been documented (Nezan, 1983; Mejule, 1974; Ivbijaro and Agbaje, 1986). Alternate stacking of bags of pepper and cowpea is said to reduce infestation of C. maculatus (E.O.R. Agbakwuru, 1995 personal communication).

Various types of vegetable and essential oils of plants such as groundnut, palm, coconut; Eucalyptus, neem, olive, garlic, African nutmeg, Dennetia tripetala G. Baker and others have been investigated for their efficacies against stored insect pests of crops. Ishaya (1989) reported that groundnut

and palm oils at the rate of 25-30 ml/kg cowpea seed provided a high level of control lasting for up to five weeks against attack of the cowpea bruchid, C. maculatus; but viability was affected. Similarly, Mital, (1971), found oil treated cowpea unattacked by weevils but reported that such seeds lost their viability. Fresh or refined palm oil achieved complete control of C. maculatus on cowpea stored for seven weeks at the rate of 6ml/kg seed (Nezan, 1983; Ajayi et al., 1987); while groundnut oil treated cowpea at 5-10ml/kg seed gave good protection of seeds beyond six months (IITA, 1985).

The insecticidal effect of plant oils in controlling insect pests is believed to be in its ability to block oxygen supply to the embryo, thereby preventing emergence of progeny rather than affecting oviposition or mortality of the adult weevil (Singh et al. 1972). However, ovicidal activity of some oils have been reported against stored insect pests (Don-Pedro, 1989). The insecticidal activity of vegetable oils was determined by the triglyceride component while for fatty acids, the main determinant is oleic acid (Schoonhoven and Hill, 1981).

### 2.3.3 NEEM PRODUCTS

Neem tree, Azadirachta indica A. Juss also known as Melia azadirachta (L.), (Meliaceae) is native to India and Burma but has now spread to other countries in Asia (including Pakistan, SriLanka, Thailand and Africa (Ghana, Nigeria, Kenya etc.) (Schmutterer, 1981 and Siddiq 1981). In Nigeria, neem was

first introduced in 1928 (probably from Ghana) where it was successfully established, in the old Bornu province. Seedlings from the first plantation were replanted in Sokoto, Katsina and Kano provinces in the 1930s with considerable success. The tree is drought resistant (Radwanski, 1981), evergreen, grows rapidly and produces numerous yellow or greenish-yellow fruits within five years and can grow to a height of up to 30 meters and 2.5 meters in girth (Schmutterer, 1981).

#### **2.3.3.1 ECONOMIC IMPORTANCE OF NEEM TREE**

Almost every part of the tree (roots, trunks, barks, leaves, flowers, fruits and seeds) have been used in various ways. For instance, the bark, root and leaves are popular amongst traditionalists for treatment of fever. Oil from the seed is used for soap making in India for treatment against skin infection. The seed cake is used for animal feeding and manure (Ketkar, 1976). In Nigeria, the tree has now become the bedrock of shelter-belts throughout the northern region and can be found along road sides and in village farms (Schmutterer, 1990). The leaf droppings provide manure and this helps in improving the fertility of poor soils (Radwanski, 1981).

#### **2.3.3.2 CHEMICAL CONSTITUENTS AND INSECTICIDAL ACTIVITIES**

Initial studies on the insecticidal properties of neem and their effects on insect species showed that the major compounds belong to a general class of natural products called

"Triterpenes" or "Limonoids", which have insect-repellent, insecticidal, anti-hormonal or anti-feedant activities (Meinwald, et al. 1978). At least nine neem "Limonoids" (Warthen 1979) have demonstrated an ability to block insect growth, affecting a range of species in Agriculture and human health. Amongst the best known "Limonoids" are Azadirachtin, Salannin, Meliatriol and Nimbin (Vietmeyer, 1992).

The most potent of the triterpenoids is azadirachtin (Kraus et al., 1981) whose chemical structure was analysed by Zanno et al. (1975) and modified by Morgan (1981). Morgan (1981) reported that these compounds are concentrated mainly in the seeds, leaves, bark and the wood in that order, but the sequence may vary accordingly due to geographical location, method of seeds preparation, storage conditions, and extraction procedures (Schoonhoven, 1981). The selective activity of neem products against many pest species have been reviewed (Pradhan and Jotwani, 1968; Meisner et al.; 1981; Abdulkareem, 1981; Ladd, 1981; Redknapp, 1981; Adhikary, 1981; Siddiq, 1981; Jacobson, 1986). Its mode of action is to repel and disrupt insect growth and reproduction (Schmutterer et al., 1982; Schmutterer and Ascher, 1984). Pradhan (1962) reported that suspension of neem kernels in water was sprayed on different crops in New Delhi, and that although, locusts landed on the plants, yet, they did not eat anything, sometimes for up to three weeks after the treatment.

Neem's insect growth regulating (IGR) effects have also

been reported. In England, Ruscoe (1972) tested azadirachtin on insect pests such as cabbage white butterfly (Pieris brassicae L.) and cotton stainer (Dysdercus fasciatus L.) and noted IGR effects in each case. Azadirachtin, salannin and nimbin all have similar basic "Limonoid" structure. Insect ingesting traces of these compounds are deeply affected because these "hormone mimics" block the parts of the brain that produce the hormones necessary for growth and development. These deep-seated hormonal effects are the reason for neem's subtle, powerful and yet insect specific influences (Vietmeyer, 1992).

Golob and Webley (1980) and Jacobson (1983) have reviewed the traditional use of some plant materials as protectants of stored products and concluded that neem products were by far the most widely used. Neem products in use include; oil, cake, kernel, leaf, bark extracts, purified fractions and their formulations. Pruthi (1937) showed the efficacy of neem leaves and cakes as being effective repellents against pests of stored wheat. Fry (1938), reported the repellent action of neem leaves mixed with cocoa beans against the Almond moth (Cadra cautella Walker). Jilani and Malik (1973) reported that water and ethanol extracts of leaves and seeds of neem repelled the red flour beetles, Tribolium castaneum Herbst; the khapra beetles, Trogoderma granarium Everts; and the lesser grain borer, Rhizopertha dominica Fab. Prakash et al. (1980) found that smoke generated by burning neem leaves

repelled grain moths from ware-houses. Neem leaves or seed powder mixed with stored maize have been confirmed to effectively reduce progeny production of Sitophilus oryzae by disrupting the larval development and adult fecundity (Pereira and Wohlgemith, 1982).

Jotwani and Scircar (1965) reported the efficacy of neem seed powder mixed with wheat grain at 1-2% and concluded that it protected the grain against S. oryzae, R. dominica, and T. granarium for about 9, 11, and 13 months respectively. Similarly, neem seed powder protected Mungbean, Bengal gram, cowpea and peas against C. maculatus feeding for about 8-11 months (Jotwani and Scircar, 1967). Dried neem seed when ground and mixed with maize protected the grains for six months against storage rice weevil, S. oryzae. Oviposition was markedly reduced at low dose and post-embryonic development was completely halted at all doses (Ivbijaro, 1983b). In addition, mortality of adult weevils reached 100% within five days. Four months, thereafter, fresh weevils placed on stored treated maize failed to lay eggs at a dose of 2.5g neem seed and 76% of them died within 10 days. Ivbijaro (1983a), stated that with one gram of neem seed, progeny emergence was delayed for six months and the number of emerging weevils was severely reduced, and the viability of treated grains was not affected and no mouldiness or shrinkage was noticed. Saxena (1987) reported that even after 12 months there was no progeny produced when C. maculatus and C.

chinensis L. adults were released in lentil seed - treated with neem seed kernel powder. Similarly, no bruchid damage occurred up to 12 months when 2% neem seed kernel powder was mixed in gram and pigeon pea seed (wt/wt). Seed protection was attributed to inhibition of oviposition of the bruchids.

Sowunmi and Akinnusi (1983) reported that 1.0 and 2.0 percent neem seed kernel powder treatments provided effective preservation of cowpea stored for eight months against C. maculatus while 0.5% admixture was effective for up to four months after which considerable grain damage was revealed. In a similar trial, admixture of dry neem seed kernel powder at the rates of 1.0 - 4.0g per 20g of cowpea seeds gave protection from damage by the bruchids, C. maculatus for more than four months (Ivbijaro 1983a). He concluded that adult C. maculatus survival was not affected by the treatments but significantly reduced fecundity, prolonged the pre-imaginal developmental period. Treated seeds were 82% viable, while the texture, colour and overall attractiveness remained unaffected.

On the efficacy of neem seed oil, to protect stored products from damage, it was found that the oil protected cowpea grains from bruchids attack for at least six months regardless of whether the beans were infested before treatment or not. Pereira (1983) reported that neem seed kernel oil at the rate of 8.0ml oil/kg of cowpea seeds reduced the rate of oviposition in addition to its ovicidal activity

and gave a good protection for up to three months against C. maculatus. Ketkar (1976) reported that application of 20% of neem seed oil to Bengal gram (vol/wt) protected it from damage by Callosobruchus spp., for six months and the impregnation of bags with neem oil at 1.0g/m<sup>2</sup> significantly reduced the population of R. dominica. Naik and Dumbre (1984) found that neem seed oil treatments prevented adult emergence and prolonged the development of C. maculatus from egg to adult stage. A progressive decrease in the number of eggs laid with increase in the oil dosage was also noticed. Similarly, Das (1987) reported that neem seed oil at the rates of 8.0 and 10.0ml oil/kg of cowpea seeds effected high egg and grub mortality when compared with the control, thereby confirming its ovicidal and larvicidal actions. Babu et al. (1989) found that seeds treated with neem seed oil appeared to repel the ovipositing females of C. chinensis as the introduced adults survived without oviposition.

The efficacies of neem extracts received the approval of the United States Environmental Protection Agency for a commercial neem based insecticide for certain non-food uses called Margosan-0(R). Henkel (1987) reported that there is a need to duplicate active ingredients of neem in the laboratory to produce a synthetic neem insecticide.

#### **2.3.4: EUCALYPTUS PRODUCTS**

The Eucalyptus spp (Myrtaceae) occur naturally in North Australia, New Guinea, Indonesia and was recently introduced

to Africa. In Nigeria, the trees were first introduced to the northern part as far back as 1916 when they were formerly planted as barefoot transplant and in 1958 seedlings were raised in polythene pots (Arnborg, 1982). Three species of Eucalyptus have been found to perform well in northern Nigeria including E. camaldulensis, E. citriodora and E. tereticornis (Dr. A.B.I. Igboanugo, 1993, personal communication). Each species of the tree presents a characteristic form which enables it to be recognized at a distance. For instance, some species have long bare-limbs with tufts of fine, feathery leaves at the ends; others have short stubby branches and dense, round crowns. Average height of Eucalyptus ranges from 10.0 to 20.0 metres. In Afaka, Kaduna State, the growth rate for E. camaldulensis is reported to be about 2.5 metres to 3.5 meters per annum in height, and 18-35 millimeters/annum in diameter.

The tree is deep-rooted and performs well in difficult sites, even where there is water stress. It is adaptable from sandy to heavy soils; is drought and frost resistant, slightly salt - tolerant, and able to withstand periodic inundation. (Arnborg 1982).

#### 2.3.4.1 ECONOMIC IMPORTANCE OF EUCALYPTUS

Eucalyptus tree is used in shelter belt establishments to serve as shade and wind breaks. The tree is also used in high way planting as ornamentals, timber, firewood, electric poles, pulp-wood or as a lawn tree (Kelly, 1969). The leaves have a

camphoraceous odour and is a source of essential volatile oils. The oil for commerce can be grouped for convenience into three classes, medicinal, industrial and perfumery according to their specific uses. Perfumery oils account for a very small fraction of the total production while medicinal and industrial oils are distilled in roughly equal proportions. The oils used for medicinal purposes contain a maximum of 70% of cineol which is the active therapeutic agent for inhalants, embrocations, soaps, gangles, sprays and lozenges (Penfold and Willis, 1961). The oil is also used in antiseptic applications as disinfectants and germicides for sheep dips or as deodorants and a source of piperitone from which thymol and menthol are manufactured (Anon, 1955).

#### 2.3.4.2 CHEMICAL CONSTITUENTS AND INSECTICIDAL PROPERTIES

The oil of different species of Eucalyptus varies in their contents of active principles and volume of oil yield. For instance, E. radiata (var. australiana) leaves yield about three to five percent oil which contains mainly cineol and terpinol useful as medicine, disinfectant and floatation for metals (Kelly 1969). Similarly, lemon scented leaves of E. citriodora contain about 0.8 to 1.0 percent oil mainly citronellol; while E. dives leaves contain between 3.0 and 4.5 percent oil usually piperitone and phellandrene, the latter is used as a solvent. The oil also contains other volatile aldehyde such as cuminal, phenol and others (Kelly, 1969).

In Nigeria, Zainab (1986) obtained different percentages

of oil from the three main Eucalyptus species grown, E. citriodora (1.9-3.0 percent); E. tereticornis (0.2 - 1.9%), E. camaldulensis (0.35-1.2%). However, the oil contents depend on a number of factors such as: the age of the leaves, storage of samples and season, time between storage and processing for oil (Zainab, 1986).

In the dry season, fresh leaves of E. citriodora yield more oil than the corresponding dried leaves. The dried leaves of both E. tereticornis and E. camaldulensis gave higher oil yields than the fresh leaves. However, the dried leaves of the three species had a higher oil yield than the corresponding fresh leaves during the rainy season (Zainab, 1986). In contrast, Penfold and Willis (1961) reported that the young leaves yield higher amounts of oil than the older leaves. Changes occur in oil content or composition between removal from the tree and distillation in a far away laboratory. Similarly, "sweating" which occurs if the leaves are tightly packed results in drastic changes in oil yield and composition. Hence, spreading the leaves loosely to prevent "sweating" is recommended (Penfold and Willis 1961). Bruno et al. (1966) reported that partial drying and withering at room temperature have been responsible for loss of citronellal (citral). The rate of evaporation of the volatile oil is increased when fresh leaves are tightly packed in polythene bags (Guenther, 1964).

Work on the use of Eucalyptus products have been

concentrated on its volatile oils used in industry, medicine and perfumery. Scanty literature is available in Nigeria on the use of Eucalyptus products in insecticidal preparations for control of C. maculatus. However, Dike and Mshelia (1996) reported that Eucalyptus leaf powder significantly ( $P < 0.05$ ) caused high mortality of C. maculatus at 20, 10 and 5 g/100g cowpea seed and inhibited oviposition and progeny development of the insect at 10 and 20g/100g cowpea seed. They concluded that cowpea seeds protected by Eucalyptus leaf powder suffered less damage than those protected by Eucalyptus stem powder. Srivastava et al.; (1988) reported that the oil of E. globulus at 0.4 percent concentration could be used for the control of C. chinensis on Cajanus cajan L. (Pigeon pea). More research is needed to explore and exploit the rich repellent and antifeedant properties of the Eucalyptus products as grain protectants during storage.

#### 2.3.5 LEMON GRASS PRODUCTS

The lemon grass, Cymbopogon citratus Staph (Gramineae) is widely distributed in Asia, South America and Africa. Two species of the plant are common in the tropics namely: C. flexuosus and C. citratus. The plant grows up to 1.0 meter tall in a bunch and its leaves are spear shaped with a pointed tip. The roots are rhizomatous and as aromatic as the leaves.

##### 2.3.5.1 ECONOMIC IMPORTANCE OF LEMON GRASS

Lemon grass has been used for various purposes such as

beverage, flavouring agent, herb for the treatment of malaria and its oil is one of the world's best known source of essential oils and accounts for its most important use. The oil is a pale sherry colour with fragrant lemon-like odour used in perfumery and cosmetic industries. Lemon grass is also used as an ornamental plant in the beautification of lawns, homes and offices. Its use for livestock feeding is not popular in Nigeria. However, Arctander (1960) reported that in some tropical countries, lemon grass is produced for cattle grazing where food is scarce.

#### 2.3.3.2. CHEMICAL CONSTITUENTS AND INSECTICIDAL PROPERTIES OF LEMON GRASS

Lemon grass oil contains 80% citral, citronellal, geraniol, methyl-heptanone, n-decyl-aldehyde and probably linalol (Poucher, 1974) all active ingredients of which are used in the manufacture of insecticides. The citral component can be produced into essential vitamins particularly vitamins A and B (Robins, 1983).

Lemon grass oil and smoke have been used effectively to repel mosquitoes and houseflies. Tiwari *et al.* (1966) reported that lemon grass extract used as a fumigant successfully achieved 100% kill of the mosquito species; Culex fatigans and Aedes aegypti within 20 minutes; and 100% elimination of house flies, Musca domestica L. Watt and Breyer (1962) attributed the effectiveness of the root stock of lemon

grass to repel moths to its aromatic fragrance. Srivastava et al. (1988) also reported that the essential oils of Cymbopogon martini tested against C. chinensis on seeds of Cajanus cajan L. was effective in its control. They reported that at a concentration of 0.1%, C. martini was most effective in preventing oviposition. They concluded that the essential oil of C. martini at 0.2 percent could be used for the control of C. chinensis on Cajanus cajan.

Dike and Mbah (1992) investigated the efficacy of stem and leaf powders of lemon grass against the cowpea bruchid and reported that lemon grass stem powder (LGSP) at 5, 10 and 20g per 100g cowpea seed gave 88.5%, 97.6% and 100% adult bruchid mortality of C. maculatus, respectively as compared with 20.0%, 38.75% and 66.25% adult mortality for similar concentrations of lemon grass leaf powder (LGLP). They concluded that lemon grass stem powder significantly retarded oviposition and progeny development at the three concentrations studied and that cowpea seeds protected by lemon grass stem powder were less damaged when compared with lemon grass leaf powder.

#### 2.3.6 GARLIC AND ONION PRODUCTS

Garlic, Allium sativum L. (Liliaceae) is a cosmopolitan plant which grows in temperate zones as well as in the tropics and subtropics. It probably originated in central Asia from where it spread to the mediterranean, around whose shores it still finds its greatest use (Puttarudriah and Bhatta, 1955).

Similarly, Onion, Allium cepa L. (Liliaceae) is the most important of the seven species in the genus Allium. The crop probably originated in the mediterranean area of western Asia, but is now cultivated in all parts of the tropics, forming one of the major vegetables of the drier regions where it grows well under irrigation.

Both Garlic and Onion are herbaceous biennial plants which produce shallow fibrous rooting systems from the base of the short stems. They are characterised by their penetrating pungent aroma which is strongest in garlic but not so strong in chives, A. schoenoprasum L. and onion.

#### **2.3.6.1 ECONOMIC IMPORTANCE OF GARLIC AND ONION**

The demand for garlic and onion is world-wide, the crops being grown and consumed by people of all nationalities and are important items of world trade. The immature and mature bulbs are eaten raw or they may be cooked and eaten as vegetables. They are used as seasoning for soups and sauces and their oils are flavouring agents produced by steaming. Medicinally, their bulbs are used for reviving convulsive patients, cure for haemorrhoids and diuretics in Nigeria (A. O. Amadi, 1993, personal communication). Garlic, from ancient time, has been recommended as a stomachic, antiseptic cure for asthma, bronchitis and coughs, treatment for epilepsy, rheumatism, leprosy, the common cold, high blood pressure, as a vermifuge, expectorant and insect repellent (Puttarudriah

and Bhatta, 1955).

#### 2.3.6.2. CHEMICAL CONSTITUENTS AND INSECTICIDAL PROPERTIES OF GARLIC AND ONION

Although, garlic has been known and used for many years, research into its chemistry, pharmacology and pesticidal aspects is relatively recent. In 1944, Cavallito *et al.* isolated an unstable sulphur-containing compound from garlic. This substance, which had antibacterial properties, was named allicin. Other sulphur-containing compounds may be obtained depending on the mode of extraction. Steam distillation yields di-allyl-disulphide; extraction with ethanol and water at 25°C gives allicin; and allim is obtained by extraction with cold ethanol (Kritchevsky, 1991).

Grainge *et al.* (1985) reported the insecticidal repellent, anti feedant, bactericidal, fungicidal, nematocidal actions of garlic and noted that the extract was effective against ticks, Mexican bean beetle, Epilachna verivestis Mulls; imported cabbage worm, Pieris rapae, Aphids and khapra beetle, Trogoderma granarium Everts.

Yepsen (1976) also reported that a fresh solution of garlic and mineral oil diluted in water was effective against the most common field pests of crops. The garlic solution should be applied immediately after preparation to prevent the volatile oils from evaporating before exerting their effects on the plants.

Nasseh (1980) reported that garlic extract reduced the

feeding of older larvae of Epilachna verivestis Muls. than younger larvae (Nasseh, 1980). However, garlic used for insecticidal purpose should not be grown with mineral fertilizers, since, heavy doses of fertilizers may reduce the concentration of the effective substances (Stoll, 1988).

#### 2.3.7 OTHER NATURAL PRODUCTS AS GRAIN PROTECTANTS

Orange peels have been used as a repellent against mosquitoes in the rural areas of Nigeria. The oils of lemon, grape fruit, lime and tangerine peels have been reported to reduce the emergence of C. maculatus on artificial black-eyed pea (Su et al., 1972). Taylor (1975) also found that orange peel powder was more toxic to C. maculatus and significantly depressed oviposition and progeny emergence than grape fruit peel powder.

The insecticidal properties of African curry leaf, Ocimum gratissimum L. have been investigated. Agina and Sani (1995) reported that smoke from the ground, dried, orange peels (Citrus sinensis L. Osbeck), African curry leaves and queen of the night (Cestrum nocturnum L.) showed 88%, 55% and 82% lethality of mosquitoes, respectively. They stated that the test materials also showed repellent effect against grain weevils, Sitophilus zeamais and Tribolium castaneum. Dried African curry leaf has been traditionally used in Nigeria to repel mosquito. The fresh leaf extracts are used for the dressing of wounds (sores) and for treatment of stomach aches (A.O. Amadi, 1993 personal communication). Onu and Aliyu (1995) reported that treating cowpea with 2.5g and 5.0g per

250g seed reduced oviposition and damage to cowpea seed and viability was not affected by the powdered pepper treatment.

Some inert substances have also been found to be effective against storage insect pests. Dung ash solution, woodash, activated coal, heat treated clay dust, ashes of rice husks and sand are effective against storage insect pests of crops (GTZ, 1980; Ahmed and Koppel, 1985). Similarly, Akibu *et al.* (1984) reported that ashes from Tamarindus indica and ground pepper were effective against groundnut, maize, sorghum and millet storage insect pests. The use of admixture of dried sand and cowpea have been reported (Kranz *et al.* 1977).

The sand filled the spaces between the grains, thereby restricting the free movement of adults and egg laying.

## CHAPTER THREE

## 3.0 MATERIALS AND METHODS

Adult C. maculatus (100 pairs) used for the study were collected from the insect culture maintained in 1000 millilitres Raven Head Kilner jars in the storage Entomology laboratory, Institute for Agricultural Research. Pure cultures of C. maculatus were raised in four, 1000ml Raven Head Kilner jars from the above sub cultures for a period of four weeks under prevailing conditions (20 and 34°C and 28-72% R.H.). The beetles were maintained on whole cowpea grains weighing 500 gms each. About 21 days after oviposition, freshly emerged adult weevils (from 0-24 hours old) were sieved out and used for artificial infestation throughout the experiments according to the method of Okeke (1986). It ensures uniformity of the insect pest used.

Cole-Palmer Hygrothermograph was used to record the daily temperature and relative humidity in the laboratory throughout the duration of the experiments. All weights were taken using a Mettler Electronic Balance PE 3000.

Plant materials used were collected from various sources in and around Zaria, and taken to the laboratory for processing. For instance, ripe neem fruits and leaves were collected from neem trees in and around I.A.R. premises in August, 1994. The leaves of Eucalyptus camaldulensis were obtained from Forestry Research Institute of Nigeria premises at Samaru, Zaria. Lemon grass stem and African bush tea were

collected from Crop Protection Department, I.A.R and around Area E, A.B.U. Housing Estate, respectively. Garlic bulbs, African curry and Onion leaves as well as Orange peels were obtained from Sabon-Gari market in Zaria. The synthetic insecticide (Pirimiphos methyl) used as standard was obtained from the storage entomology laboratory.

Moisture contents (M.C) of the cowpea and all the plant materials used were determined prior to the experiments using oven-dried method (Pixton, 1967). However, all the plant materials used in the experiments except garlic bulbs, neem seed and lemon grass stem were dried in the laboratory for three days before samples of each material in two replications were weighed into the oven for M.C. determination. Plant materials were oven dried for 24 hours at 60°C (except for Garlic bulbs that were dried at 80°C for 4 hours in order to reduce the volatilization of the pungency).

The percentage moisture content (Appendix 12) of each sample was calculated as follows:-

$$\%M.C = \frac{\text{Initial sample weight} - \text{final sample weight} \times 100}{\text{Initial sample weight}}$$

The mean percent moisture content for each sample (replicated two times) was calculated by summing up the M.C and dividing by two.

After drying, the samples were separately ground in a Hammer-mill and sieved into fine powders using 0.1mm wire-mesh sieve. For neem seed, garlic bulb and lemon grass stem, these were

placed in a desiccator after oven drying to prevent moisture absorption on cooling and thereafter were separately ground in a hammer-mill located in Food Science and Technology Laboratory, I.A.R, Zaria. The ground materials were packed in white polythene bags and stored in a refrigerator at 4°C until required for use.

### **3.1.0 EVALUATION OF PLANT POWDERS AND ACTELIC DUST FOR CONTROL OF C. MACULATUS ON STORED COWPEA**

One hundred grams of cowpea were placed in each kilner jar. Powders of plant materials were applied at three different levels of 2.5g, 5.0g and 10.0g to each jar and replicated three times. The rates for pirimiphos methyl were 1.0g, 2.0g and 3.0g per 100 grams cowpea and these were also replicated three times. The control was made up of three jars containing 100g cowpea each without any treatment.

All the jars excluding the 'control' were vigorously shaken to ensure proper mixing. The powder in each jar was allowed to settle for two hours. Ten pairs of freshly emerged adult bruchids, were introduced into each jar including the control. The jars were then loosely covered to allow for ventilation. All the kilner jars were carefully labelled and arranged in a randomised complete block design (RCBD) on the laboratory bench at room temperature for a period of 12 weeks.

**3.1.1 EFFECT OF PLANT POWDERS AND ACTELIC DUST ON  
MORTALITY OF ADULT C. MACULATUS**

In each treatment, observations were made for toxicity symptoms while mortality rates were recorded in all the jar at 24 hours, 48 hours and in the 7th day of exposure. The survivors were placed back into the jars while dead insects were removed each time until the 7th day. The data obtained were transformed and subjected to analysis of variance (ANOVA) tests.

**3.1.2 EFFECT OF PLANT POWDERS AND ACTELIC DUST ON  
OVIPOSITION AND PROGENY EMERGENCE OF C. MACULATUS**

After 15 days of exposing the beetles to treatments, 20 grains of cowpea were randomly removed from each jar to ascertain the number of eggs layed on them. All introduced insects (dead or alive) were sieved out and the sampled grains returned to their respective jars.

The test for progeny emergence took place at 4, 8 and 12 weeks for F1, F2 and F3, respectively, when newly emerged adults were sieved out and recorded. The data obtained for oviposition and progeny emergence were transformed and subsequently analysed statistically and compared with the control and with one another.

**3.1.3 EFFECT OF PLANT POWDERS AND ACTELIC DUST ON INFESTATION LEVELS AND LOSS IN WEIGHT OF STORED COWPEA DUE TO C. MACULATUS AFTER 12 WEEKS**

At the end of 12 weeks, the percentage of infested (damaged) grains and weight losses from the same sample were evaluated by randomly picking 100 seeds from each jar and recording the number of emergence holes in them, as well as weighing the entire cowpea grains in each jar. The data for each replicate was recorded and subjected to analysis of variance tests.

To calculate the percentage of damaged seeds and loss in weight, the formulae below were used:-

- i Percentage of damaged seeds  

$$= \frac{\text{Initial NO. of seeds} - \text{Number of undamaged seeds}}{\text{Initial number of seeds}} \times 100$$
- ii Percentage loss in weight  

$$= \frac{\text{Initial seed weight} - \text{Final seed weight}}{\text{Initial seed weight}} \times 100$$

**3.1.4 EFFECT OF PLANT POWDERS AND ACTELIC DUST ON GRAIN VIABILITY AFTER 12 WEEKS OF STORAGE**

At the end of the trial period (12 weeks), 20 undamaged seeds from each treatment were picked and placed on Whatman number one filter paper in sterilized Petri dishes, moistened and kept on the laboratory bench under room temperature. Germination counts were taken on the 7th day and data obtained

was subjected to analysis of variance after after transformation.

### **3.1.5 EFFECT OF PLANT POWDERS AND ACTELIC DUST ON GRAIN QUALITY AFTER 12 WEEKS OF STORAGE**

Organo-leptic studies were conducted at the termination of the experiments. Cowpea grains from each concentration (for example - 2.5, 5.0 and 10.0g for plant extracts and 1.0g, 2.0g and 3.0g for actellic dust) were separately boiled, and tested for palatability and retention of flavour of treatment materials. Ten respondents (five males and females) were trained and used to assess the palatability of cooked grains on a scale of one to five (very poor, poor, fair, good and very good).

Observations were also made on the seed coat of grains from each treatment to assess visually any changes in texture, colour and growth of moulds which may likely hinder market appeal for the products. The scale of 1 to 3 (Poor, Fair and Good) was used and normal frequency distribution was applied in data analysis for all quality factors.

## CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSIONS

4.1. EFFECT OF PLANT POWDERS AND ACTELIC DUST ON MORTALITY OF ADULT CALLOSOBRUCHUS MACULATUS ON STORED COWPEA.

The results of the relative efficacies of various phytochemicals and pirimiphos methyl (Actellic dust) on the mortality of adult cowpea weevils after 24, 48 hours and 7 days are shown in Tables 1, 2, 3. After 24 hours, the effects of plant powders on the mortality of adult C. maculatus were varied. Neem seed powder (NSP), Lemon-grass stem powder (LGSP), Orange peel powder (OPP), Garlic bulb powder (GBP), Eucalyptus leaf powder (ELP), African curry leaf powder (ACLP) and Actellic dust (AD) with an occasional exertion, achieved more than 20 percent mortality of adult C. maculatus. Hyptis (African Bush tea) leaf powder (HLP), Neem leaf powder (NLP) and Onion leaf powder (ONLP), had less than 20 percent mortality. Many of the treatments as shown in Table 1 were significantly ( $P < 0.01$ ) better than the control which recorded no insect mortality during the period. Actellic dust at the highest level (3.0g wt/wt) performed significantly ( $P < 0.01$ ) better than the plant extracts by recording 100 percent adult weevil mortality.

Table 1: Effects of plant powders and actellic dust on percentage mortality of *C. maculatus* at 24 hours post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust	71.67 (8.46a)	85.0 (9.22a)	100.0 (10.02a)	85.56 (7.10a)
Neem Seed Powder	25.0 (5.03abc)	31.67 (5.62abc)	46.67 (6.84abc)	34.45 (4.55abc)
Lemon Grass Stem Powder	26.67 (5.04abc)	33.33 (5.68abc)	35.0 (5.85abc)	31.66 (4.32abc)
Garlic Bulb Powder	18.33 (3.98abc)	23.33 (4.54abc)	45.0 (6.59abc)	28.89 (4.03abc)
Orange Peel Powder	18.33 (3.98abc)	23.33 (4.54abc)	35.0 (5.52abc)	25.55 (3.48abc)
Eucalyptus Leaf Powder	36.67 (6.08abc)	38.33 (6.04abc)	46.67 (6.83abc)	40.56 (4.91abc)
African Curry Leaf Powder	46.67 (6.85ab)	46.67 (6.80ab)	65.0 (8.04ab)	52.78 (5.60ab)
Hyptis Leaf Powder	1.67 (1.25bc)	3.33 (1.80bc)	8.33 (2.63bc)	4.44 (1.60c)
Neem Leaf Powder	5.0 (2.10abc)	6.67 (2.64abc)	8.33 (2.88bc)	6.67 (2.08bc)
Onion Leaf Powder	5.0 (2.10abc)	8.33 (2.63abc)	13.33 (3.70abc)	8.89 (2.28bc)
Control (0.0)	0.0 (0.71e)	0.0 (0.71e)	0.0 (0.71e)	0.0 (0.71e)
LSD x DMRF (0.01)	6.67	6.67	6.67	3.91
Concentration Means	4.52a	4.87a	5.89a	0.71b control
LSD (P<0.01)	4.45	4.45	4.45	4.45

\* Figures in parenthesis are transformed (square root) from the original data.

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Horizontal comparison made for concentration means.

\* Concentration of Actellic dust (g): 1.0; 2.0 and 3.0

\* Number of insects used = 20

Amongst the plant products, ACLP recorded the highest mortality (46.67, 46.67 and 65.0% respectively at the three levels tested); followed by ELP (36.67, 38.33 and 46.65%), NSP (25.0, 31.67, 46.67%), LGSP (26.25, 33.33, 35.0%). GBP caused higher ( $P < 0.01$ ) mortality (45%) at 10 g than LGSP and OPP at similar levels. The lowest adult beetle mortality during the period was observed in HLP treatments (1.67%). Similarly, NLP and ONLP recorded one of the lowest mortality especially at the lower concentrations.

The analysis of variance (Appendix 1), for this period (24 hours) indicated that within the treatments, significant differences ( $P < 0.01$ ) existed in adult weevil mortality. The interaction between concentrations and treatments was found to be significant ( $P < 0.01$ ) too.

At 48 hours post treatment, a similar trend of increased mortality was observed. A cumulative mortality of over 60 percent was recorded in cowpea treated with NSP (which had the highest mortality in all treatment levels). Dosage level of 10.0g NSP per 100g cowpea seed wt/wt gave the highest mortality (98.34%) followed by ACLP (80.0%, and 75.0% at 10.0g and 5.0g levels respectively), GBP (75.0%), ELP (73.32%) and LGSP (68.33%) at the highest concentration. Actellic dust which earlier recorded a 100 percent mortality of adult beetles at the highest concentration, also achieved 100% mortality at the lower treatment levels (Table 2).

This result showed that AD achieved higher ( $P < 0.01$ ) mortality than all the plant products. The lowest beetle mortality at 48 hours post treatment was observed in cowpea treated with ONLP which earlier performed better than NLP

Table 2: Effect of plant powders and Actellic dust on percentage mortality of *C. maculatus* at 48 hours post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	100.0 (10.02a)	100.0 (10.0a)	0.0 -	100.0 (5.36bed)
Neem Seed Powder	93.33 (9.68ab)	93.33 (9.68ab)	98.33 (9.94a)	95.0 (7.50a)
Lemon Grass Stem Powder	56.67 (7.55bed)	66.67 (8.12abc)	68.33 (8.27ab)	63.89 (6.16abc)
Garlic Bulb Powder	50.0 (7.03ede)	56.67 (7.36bed)	78.33 (8.86ab)	61.67 (5.99bc)
Orange Peel Powder	40.0 (6.05def)	36.67 (5.46de)	55.0 (7.10bc)	43.89 (4.83ede)
Eucalyptus Leaf Powder	71.67 (8.49abc)	55.0 (7.37bed)	73.33 (8.53ab)	66.67 (6.27ab)
African Curry Leaf Powder	73.33 (8.59abc)	75.0 (8.69ab)	80.0 (8.95ab)	76.11 (6.73ab)
Hyptis Leaf Powder	15.0 (3.94f)	18.33 (4.33e)	31.67 (5.67c)	21.67 (3.66c)
Neem Leaf Powder	15.0 (3.90f)	36.67 (5.98ede)	45.0 (6.74bc)	32.22 (4.33de)
Onion Leaf Powder	25.0 (4.94ef)	31.67 (5.67de)	25.0 (5.01c)	27.22 (4.08de)
Control (0.0)	0.0 (0.71g)	0.0 (0.71f)	0.0 (0.71d)	- -
LSD x DMRF (0.01)	2.36	2.36	2.36	1.38
Concentration Means	7.020a	7.260a	6.980a	0.710b (control)
LSD (P < 0.01)	1.57	1.57	1.57	1.57

\*\* Actellic dust concentration (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

and HLP. However, Neem leaf and Hyptis leaf powders showed an improvement over their previous data at 24 hours; by recording 40.0% and 31.66% respectively, of adult beetle mortality. Similarly, there was no death recorded in the control during the period. The longevity of female C. maculatus is between two and fourteen days depending on temperature and the peak oviposition is 2-3 days after emergence. Since some of the plant powders achieved more than 50% beetles mortality within 48 hours, the number of eggs laid could be reduced significantly and this would in turn affect the number of adults that may emerge (Tun, 1979).

At the seventh day post treatment, all the treatment levels achieved 100 percent beetles mortality compared with the control (53.33%) which could be due to natural factors (e.g Senescence) (Table 3). The differences between the treatments and control and the interaction between treatments and concentrations were highly significant ( $P < 0.01$ ). This result showed that up to 100 percent mortality can be achieved using the plant products under investigation, although, it took a longer time to be effective as compared with the conventional insecticide.

Table 3: Effect of plant powders and acetlic dust on percentage mortality of *C. maculatus* at 7 days post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Acetic Dust**	0.0	0.0	0.0	0.0
Neem Seed Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Lemon Grass Stem Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Garlic Bulb Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Orange Peel Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Eucalyptus Leaf Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
African Curry Leaf Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Hyptis Leaf Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Neem Leaf Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Onion Leaf Powder	100.0 (10.03a)	100.0 (10.03a)	100.0 (10.03a)	100.0 (9.34a)
Control (0.0)	53.33 (7.30b)	53.33 (7.30b)	53.33 (7.30b)	-
LSD x DMRF (0.01)	0.87	0.87	0.87	0.51
Concentration Means	9.09a	9.09a	9.09a	7.30b (control)
LSD (P < 0.01)	0.58	0.58	0.58	0.58

\*\* Concentration of Acetic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

The mode of action of these products is not clearly understood but AD, ACLP, ELP and NSP may have a contact action, since these products caused more than 50% mortality of adult C. maculatus within 48 hours. The improvement in efficacy of neem products after 24 hours post treatment may be due to its oil exudate which was clearly visible and may have been responsible for its contact action by blocking the respiratory tracts of the insects (Singh et al., 1977).

Several workers had observed relative efficacies of plant powders in effecting mortality of adult bruchid in stored produce. Ivbijaro (1983a) reported that within 24 hours of exposure, 47% of Sitophilus oryzae adults died at 2.5g; 13% at 1.0g and 6% at 0.5g neem seed powder per 20g of maize respectively. He concluded that mortality reached 100% on day 10 at the doses of 0.5 and 1.0g NSP while the untreated control recorded only 38% mortality of beetles. Usman (1991) reported that after three days, the effects of neem seed powder on the mortality of adult T. castaneum were very low. In all the NSP treatments, less than 20% mortality was achieved with the highest amount of NSP 24 hours after treatment.

Dike and Mbah (1992), Dike and Mshelia (1996) and Agina and Sani (1995) have reported high mortality of beetles when treated with lemon grass products, Eucalyptus products and African curry leaf powder respectively. Onu and Sulyman (1997) reported that grapefruit peels produced significantly higher levels of C. maculatus mortality at 10g and 20g per

200g seeds than sweet orange, lime orange, lemon treatments and the control after 96 hours of treatment. The above results were consistent with the ones obtained in the present study.

Generally, there were relative increases in efficacies as the concentration of products increased, showing that there is a possibility of achieving higher mortality of adult beetles if the concentration of powders is increased beyond 10.0g but these powders may be too bulky to handle. Other factors that could affect potency of plant powders include stage of plant leaves used, method of processing (Penfold and Willis, 1961), mode of application, health condition of the insects, differences in insect bio-type (Jacobson, 1983), experimental conditions such as temperature and humidity, (Tun, 1979) and stage of maturity of seeds or bulbs used (Stoll, 1988).

#### 4.2. EFFECT OF PLANT POWDERS AND ACTELIC DUST ON OVIPOSITION OF C. MACULATUS AT 15 DAYS POST TREATMENT.

The effect of plant powders and actellic dust on the oviposition of C. maculatus at 15 days post treatment are summarized in Table 4. The analysis of variance of the data (Appendix 4), followed by comparison and ranking using Duncan's Multiple Range Test (DMRT) showed that the means of eggs layed between treatments and within treatments were significantly ( $P < 0.01$ ) lower than those in the control (250.33). Neem Seed Powder (NSP) recorded the least mean number of eggs deposited (5.33, 3.33, 2.67 for 2.5g, 5.0g,

Table 4. Effect of plant powders and actellic dust on oviposition of *C. maculatus* at 15 days post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
	Plant powders conc.			
Actellic Dust**	(5.07)cd 25.67	(3.62)cd 13.33	(2.84)de 8.0	(8.62)bc 74.3
Neem Seed Powder	(2.38)d 5.33	(1.90)d 3.33	(1.76)e 2.67	(8.09)c 65.4
Lemon Grass Stem Powder	(7.22)bc 59.0	(6.62)bc 44.0	(5.48)bcd 35.67	(9.88)abc 97.7
Garlic Bulb Powder	(9.37)b 94.0	(9.61)b 93.33	(6.20)bed 40.33	(10.93)a 119.5
Orange Peel Powder	(9.38)b 91.67	(8.65)b 78.67	(7.36)bc 59.67	(10.95)a 120.10
Eucalyptus Leaf powder	(7.61)bc 63.67	(7.39)bc 58.0	(7.36)bc 55.67	(10.34)ab 106.9
African Curry Leaf Powder	(4.74)cd 22.33	(3.58)cd 17.33	(3.56)cde 13.67	(8.71)bc 75.9
Hyptis Leaf Powder	(7.66)bc 60.33	(7.58)b 57.33	(6.64)bed 48.33	(10.20)ab 104.10
Neem Leaf Powder	(7.70)bc 64.33	(7.18)bc 52.0	(5.83)bed 33.67	(10.01)abc 100.10
Onion Leaf Powder	(8.14)bc 66.33	(8.01)b 64.67	(7.55)b 56.67	(10.46)ab 109.50
Control (0.0)	(15.83)a 250.33	(15.83)a 250.33	(15.83)a 250.33	- -
LSD x DMRF (0.01)	3.38	3.38	3.38	2.05
Concentration Means	7.74b	7.28b	6.40b	15.83a (control)
LSD (P<0.01)	1.84	1.84	1.84	1.84

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Number grains used each = 2.0

\* Horizontal comparison made for concentration means.

10.0g wt/wt per 100g cowpea seed respectively). This was followed by Actellic dust (25.67, 13.33, 8.0 for 1.0g, 2.0g, 3.0g wt/wt respectively); African curry leaf powder-ACLP (22.33, 17.33, 13.67, for 2.5g; 5.0g, 10.0g w/w respectively).

Other plant powders with significantly ( $P < 0.01$ ) reduced oviposition at 10.0g w/w compared with the control in descending order include NLP, LGSP, GBP, HLP, ELP, ONLP and OPP. NSP, AD and ACLP reduced oviposition by 48 to 95 times and 11 to 19 times, respectively with respect to the control. Onu and Sulyman (1997) reported that grapefruit and lime peel treatments at 5 and 10% (w/w) caused a significant reduction in oviposition rate 40 days post treatment; however, the oviposition rates on seeds treated with sweet orange and lemon peels at both rates were not significantly different from the control. Similarly, Dike and Mbah (1992), Dike and Mshelia (1996) and Onu and Aliyu (1995) observed significant reduction in oviposition on cowpea treated with Lemon grass, Eucalyptus and pepper products, respectively.

Ivbijaro (1983a) has reported that NSP products drastically reduced egg laying in female Sitophilus oryzae from 154 in untreated control to only 9 and 3 at neem seed doses of 0.5g and 1.0g per 20g of maize, respectively.

The highest mean oviposition amongst the products was observed on cowpea treated with garlic bulb at the two lower

concentrations (94.0, 93.33 for 2.5g and 5.0g respectively). Other plant powders with high oviposition at lower concentrations include OPP, ONLP, ELP, NLP and HLP. The reason for high oviposition rates observed was partly due to low levels of powders used, the caking nature of the products with time as a result of constant exposure of the powdery materials (especially GBP and LGSP) to the atmosphere during data collection. In addition, Stoll (1988) had reported a reduction in the efficacy of garlic as insecticide when grown with inorganic fertilizers and this may have accounted for its relative ineffectiveness in suppressing beetles oviposition in the present study.

Therefore, for plant powders (especially GBP and LGSP) to be effective for a long time in the course of treatment, the container should not be opened except for replacement of powders used in treatment in order to prevent moisture absorption from the surroundings. Also, inorganic fertilizers should not be applied to garlic to be used for insecticidal purposes. Since the results as shown in Table 4 indicates a reduction in the number of eggs laid as the concentration of powders is increased; high doses of powders (probably at

10.0g/100g seed) may be adequate to discourage oviposition by beetles on stored cowpea.

The mode of action of plant powders in reducing oviposition of female C. maculatus is not fully understood but higher mortality rates (Dike and Mbah, 1992) as well as repellent activity of the products (Babu et. al. 1989) which disorientated the bruchids and forced them to migrate to the wall of the jars where they laid most of their eggs, could be implicated.

#### **4.3. EFFECT OF PLANT POWDERS AND ACTELIC DUST ON ADULT EMERGENCE OF C. MACULATUS.**

The effect of plant powders and actellic dust on adult emergence of three generations of C. maculatus is shown in Tables 5, 6, and 7. Progeny emergence in all treatment concentrations at four weeks after treatment (WAT) followed a sequence similar to that of egg count at 15 days after treatment (DAT).

The analysis of variance of these means (Appendix 5) showed highly significant differences ( $P < 0.01$ ) between the treatments and the control on one hand, and between and within treatments on the other. The interaction between treatments and concentration on F<sub>1</sub> progeny emergence was highly significant ( $P < 0.01$ ) (Appendix 5). Table 5 indicates that 100 percent inhibition of F<sub>1</sub> progeny of C. maculatus was achieved with NSP at 5.0g and 10.0g w/w followed by 93.81 percent at 2.5g w/w. Other materials which had above 50 percent

Table 5. Effect of plant powders and actellic dust on percentage F<sub>1</sub> progeny of *C. maculatus* at four weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)				% Inhibition of F <sub>1</sub>		
	Plant powders conc.			Chemical Means	2.5g	5.0g	10.0g
	2.5g	5.0g	10.0g				
Actellic Dust**	61.04 (7.81a)	39.98 (6.32d)	25.0 (5.0e)	52.68 (7.26c)	38.96	60.02	75.0
Neem Seed Powder	6.19 (2.49b)	0.0 (0.71c)	0.0 (0.71f)	22.72 (4.77d)	93.81	100.0	100.0
Lemon Grass Stem Powder	74.58 (8.64a)	70.45 (8.39abc)	69.99 (8.37ab)	74.72 (8.64ab)	25.42	29.55	30.84
Garlic Bulb Powder	68.09 (8.25a)	59.28 (7.70a-d)	38.01 (6.17de)	62.52 (7.91abc)	31.91	40.72	61.99
Orange Peel Powder	83.64 (9.15a)	83.48 (9.14ab)	66.48 (8.15abc)	79.57 (8.92a)	16.36	16.52	33.52
Eucalyptus Leaf powder	76.44 (8.74a)	56.90 (7.54(a-d)	46.11 (6.79b-e)	66.04 (8.13abc)	23.56	43.10	53.89
African Curry Leaf Powder	55.22 (7.43a)	53.84 (7.34bcd)	41.48 (6.44cde)	58.81 (7.67bc)	44.78	46.16	58.52
Hyptis Leaf Powder	75.15 (8.67a)	72.09 (8.49abc)	58.62 (7.66a-d)	72.64 (8.52ab)	24.86	27.91	41.38
Neem Leaf Powder	68.91 (8.30a)	51.92 (7.21cd)	46.54 (6.82bcd)	63.02 (7.94abc)	31.09	48.08	53.46
Onion Leaf Powder	77.39 (8.80a)	76.81 (8.76abc)	73.53 (8.58ab)	78.11 (8.84a)	22.61	23.19	26.47
Control (0.0)	84.69 (9.20a)	84.69 (9.20a)	84.69 (9.20a)	-	15.31	15.31	15.31
LSD x DMRF (0.01)	1.80	1.80	1.80	1.05	-	-	-
Concentration Means	(7.95b)	(7.35bc)	(6.72c)	(9.20a) (Control)			
LSD (P<0.01)	1.20	1.20	1.20	1.20			1.84

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Horizontal comparison made for concentration means.

\* Figures in parenthesis are transformed (square root) from original data.

\* % F<sub>1</sub> Emergence =  $\frac{F_1 \text{ Mean}}{\text{Oviposition Mean}} \times 100$

Oviposition Mean = 1

\* % F<sub>1</sub> Inhibition = 100 - %F<sub>1</sub> Emergence.

Table 6: Effect of plant powders and actellic dust on F<sub>2</sub> progeny of *C. maculatus* at eight weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	39.0 (6.19bcd)	24.0 (4.77bc)	17.0 (4.15bc)	95.0 (7.99bc)
Neem Seed Powder	0.0 (0.71d)	0.0 (0.71c)	0.0 (0.71c)	75.0 (4.74c)
Lemon Grass Stem Powder	50.0 (7.08bcd)	35.0 (5.91bc)	34.0 (5.84bc)	104.8 (8.92ab)
Garlic Bulb Powder	158.0 (12.51ab)	131.0 (11.41ab)	35.0 (9.01b)	167.5 (12.44a)
Orange Peel Powder	133.0 (11.49abc)	122.0 (10.75ab)	69.0 (8.28b)	156.0 (11.84a)
*Eucalyptus Leaf Powder	80.0 (8.97bc)	67.0 (8.21b)	47.0 (6.85bc)	123.5 (10.22ab)
African Curry leaf Powder	31.0 (5.60cd)	22.0 (4.71bc)	13.0 (3.63bc)	91.05 (7.70bc)
Hyptis Leaf Powder	62.0 (7.82bc)	51.0 (7.15bc)	36.0 (6.01bc)	112.3 (9.46ab)
Neem Leaf Powder	60.0 (7.74bc)	52.0 (7.14bc)	38.0 (6.13bc)	112.5 (9.47ab)
Onion Leaf Powder	68.0 (7.98bc)	61.0 (7.78b)	61.0 (7.73b)	122.5 (10.09ab)
Control (0.0)	300.0 (16.85a)	300.0 (16.85a)	300.0 (16.85a)	- -
LSD x DMRF (0.01)	6.76	6.76	6.76	3.76
Concentration Means	7.61b	6.85b	5.83b	16.85a(Control)
LSD (P<0.01)	3.86	3.86	3.86	3.86

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

Table 7: Effect of plant powders and actellic dust on *F<sub>3</sub>* progeny of *C. maculatus* at 12 weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	46.0 (6.72)d	31.0 (5.58)efg	23.67 (4.86)cde	9.28f
Neem Seed Powder	0.0 (0.71)e	0.0 (0.71)g	0.0 (0.71)e	5.53h
Lemon Grass Stem Powder	174.0 (13.19)bc	167.0 (12.90)bed	138.0 (11.74)b	14.45b
Garlic Bulb Powder	338.33 (18.32)ab	330.67 (18.19)ab	88.33 (9.41)bed	16.48a
Orange Peel Powder	311.0 (17.50)ab	233.33 (15.01)abc	169.67 (12.84)b	16.34a
Eucalyptus Leaf Powder	109.33 (10.41)cd	101.67 (10.06)cde	76.0 (8.61)bed	12.27d
African Curry Leaf Powder	35.0 (5.93)de	18.0 (4.29)fg	16.67 (4.13)de	8.58g
Hyptis Leaf Powder	93.33 (9.63)cd	75.33 (8.55)def	64.67 (7.98)bed	11.54e
Neem Leaf Powder	86.0 (8.88)cd	72.33 (8.49)def	51.0 (7.49)bed	11.21e
Onion Leaf Powder	131.67 (11.13)cd	126.0 (11.22)cd	102.0 (10.07)bc	13.10c
Control (0.0)	404.33 (19.98)a	404.33 (19.98)a	404.33 (19.98)a	-
LSD x DMRF (0.01)	5.35	5.35	5.35	2.97
Concentration Means	10.24b	9.50b	7.78b	19.98a (Control)
LSD (P<0.01)	3.06	3.06	3.06	3.06

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

inhibition of  $F_1$  progeny emergence compared with the control (15.31) included Actellic dust, 75.0 percent and 60.02 percent for 2.0g and 3.0g w/w respectively; GBP 61.99 percent; ACLP 58.52 percent; ELP 53.89 percent; NLP 53.46 percent for 10.0g w/w. These products exhibited three to seven times effective suppression of  $F_1$  emergence above the control. From the same data, it was observed that as the concentration of plant powders is increased, the percentage adult  $F_1$  development decreased. Plant products with less than 50 percent inhibition of  $F_1$  at all three treatment levels were LGSP, HLP, OPP, and ONLP.

The poor performance recorded on LGSP, HLP, and OPP may be due to either their hygroscopic nature which resulted in caking and/or the settling of the powders at the bottom of the Kilner-jars. However, Dike and Mbah (1992) reported that Lemon-grass products effectively retarded progeny development of C. maculatus on stored cowpea. The mode of action of AD, GBP, NSP, ACLP, ELP and NLP in suppressing  $F_1$  development is not clearly understood; but it may be due to ovicidal activity which resulted in reduced larval exclusion (Gbolade and Adebayo, 1993; Pereira and Wohlgemith, 1982).

On the development of subsequent generations ( $F_2$  and  $F_3$ ), the ANOVA (Appendix 6 and 7) showed that there were highly significant differences ( $P < 0.01$ ) between the levels of treatments and the control at  $F_2$  and  $F_3$  and between the treatments at  $F_3$  only. The interaction between the treatments and concentration was also highly significant at  $F_3$  only.

Data on Tables 5 and 6 show that NSP completely inhibited the development of  $F_2$  and  $F_3$  progenies while ACLP and AD in that order performed better than other plant products at all the treatment levels.

The complete inhibition and/or suppression of progeny development in the  $F_2$  and  $F_3$  generations by NSP and ACLP respectively is perhaps the first time this finding is being reported in a laboratory study. The finding suggests that the powders of neem seed and African curry leaves may have some adverse effects on some of the eggs laid by the parental female bruchids. Thus, adults which developed from such eggs were rendered infertile (Lale and Ajayi, 1996). Although, the precise nature of the sterilizing effect of the powders of neem seed and African curry leaves on bruchid eggs is not known, this particular mode of action of this class of plant powders offers great prospects for the management of cowpea bruchids in developing countries (Lale and Ajayi, 1996).

The mean numbers of  $F_2$  and  $F_3$  that emerged on ACLP were 31.0, 22.0, 13.0 and 35.0, 18.0, 16.66, respectively, for the three levels while AD had 39.0, 24.0, 17.0; and 46.0, 31.0, 23.66, respectively, for all the levels. However, some plant products showed good suppression of  $F_2$  progenies at the highest treatment level. These products include LGSP, GBP, HLP, NLP and ELP with mean adult emergence of 34, 35, 36, 38 and 47, respectively. The means for adult emergence in  $F_2$  and  $F_3$  generations in the control were 300 and 404.33, respectively. Generally, there were significant increases in progeny development from  $F_1$  to  $F_3$  in all treatments except NSP and ACLP in which adult increased with increasing generations

only at the 5.0g w/w level. The fact that there were more progenies in each generation up to 12 WAT on cowpea seeds indicates the need for a repeat treatment to be applied in some cases.

The reason for this progressive loss of potency may apparently be attributed to the constant exposure of the powders during data collection and the settling of the powder particles at the bottom of the container (Cobbinah and Applahkwarteng, 1989). It could also be partly due to the fact that the insecticidal principles in the plant (probably in small amounts) might be volatile in nature and might have been lost during the drying and grinding stages (Adebayo and Gbolade, 1994, Lale, 1994).

#### 4.4. EFFECT OF PLANT POWDERS AND ACTELIC DUST ON PERCENTAGE DAMAGE OF COWPEA BY C. MACULATUS AT 12 WEEKS POST TREATMENT.

The results of the effect of plant products and Actellic dust in protecting cowpea from attack by C. maculatus are shown in Table 9. All the treatments showed significant ( $P < 0.01$ ) protection of cowpea stored for 12 weeks against C. maculatus as compared with the control.

The percentage damage (holes in the grains) was least on cowpea treated with NSP at the three concentrations (0.67%, 0.33%, 0.0%). This was followed by Actellic dust (25.0, 21.33, 13.66%); African curry leaf powder (33.0, 20.66, 16.66%) and Lemon grass-stem powder (40.66, 40.0, 36.66%) for low, middle and highest concentrations respectively. Plant powders with less than 50 percent cowpea damage in descending order were garlic bulb powder (38.66%), Eucalyptus leaf powder

Table 8: Effect of plant powders and actellic dust on percentage grain damage caused by *C. maculatus* at 12 weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	25.0 (4.93ab)	21.33 (4.66ab)	13.67 (3.70bc)	33.90 (5.50a)
Neem Seed Powder	0.67 (1.05a)	0.33 (0.88c)	0.0 (0.71c)	19.20 (2.84b)
Lemon Grass Stem Powder	40.67 (6.02a)	40.0 (6.33ab)	36.67 (5.68ab)	48.30 (6.69a)
Garlic Bulb Powder	72.0 (8.26a)	68.0 (8.19ab)	38.67 (6.26ab)	63.60 (7.86a)
Orange Peel Powder	65.0 (7.99a)	58.33 (7.45ab)	44.33 (6.49ab)	60.80 (7.66a)
Eucalyptus Leaf Powder	55.33 (7.39a)	55.33 (7.21ab)	38.33 (6.17ab)	56.30 (7.38a)
African Curry Leaf Powder	33.0 (5.76a)	20.67 (4.28bc)	16.67 (3.93bc)	36.50 (5.67a)
Hyptis Leaf Powder	66.33 (8.04a)	55.33 (7.26ab)	54.0 (7.24ab)	62.80 (7.81a)
Neem Leaf Powder	59.33 (7.57a)	54.67 (7.43ab)	44.0 (6.42ab)	58.40 (7.53a)
Onion Leaf Powder	60.33 (7.65a)	57.67 (7.40ab)	53.67 (6.95ab)	67.80 (7.68a)
Control (0.0)	75.67 (8.73a)	75.67 (8.73a)	75.67 (8.73a)	- -
LSD x DMRF (0.01)	4.24	4.24	4.24	2.36
Concentration Means	6.47	6.11	5.35	8.73 (Control)
LSD (P < 0.01)	2.42	2.42	2.42	2.42

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Horizontal comparison made for concentration means.

\* The number of seeds selected = 100

\* Figures in parenthesis are transformed (square root) from original data.

(38.66%), Neem leaf powder (44.0%) and Orange peel powder (43.33%) all at the highest concentration (10.0g w/w). These observations are similar to those of Dike and Mbah (1992); Dike and Msheila (1996); Onu and Sulyman (1997) and Taylor (1975); using LGSP, ELP and Citrus peels powder respectively to protect stored cowpea grains. The highest damage to cowpea by C. maculatus was observed in the control (75.0%) which did not differ significantly ( $P>0.01$ ) from GBP (72.10%) at the lowest concentration. Other treatments with more than 50 percent infestation level included Hyptis leaf powder (range 54.0-66.33%) and Onion leaf powder (range 53.66-60.33%). Generally, the result shows a decreasing damage level of cowpea by weevils as the concentration of treatment is increased.

The effectiveness of Neem seed, Actellic dust, African curry leaf, Lemon-grass stem, Garlic bulb, Orange peel and Neem leaf powders in protecting cowpea stored for three months against bruchid attack may be due to the suppression of progeny development, through oviposition deterrence and ovicidal actions (Ivbijaro, 1983a; Pereira, 1983; Ali et al. 1983; Sowunmi and Akinnusi, 1983; Das and Karim 1986 and Das, 1987). The result also shows that African curry leaf powder competes favourably well with Actellic dust in protecting stored cowpea, although, the latter was slightly more effective. Yadav (1973) reported that lentil seeds treated with neem kernel powder were protected from C. chinensis and that there was no bruchid damage when two percent Neem kernel

powder was mixed with pigeon pea seeds (wt/wt) after 12 months of storage. Seed protection was attributed to inhibition of oviposition of the bruchid. Similarly, Jotwani and Scircar (1965) reported that 1-2 percent powdered neem kernel mixed with wheat grain (wt/wt) protected the grain against the rice weevil (Sitophilus oryzae), the lesser grain borer (Rhyzopertha dominica) and the Khapra beetle (Trogoderma granarium) for about 9-12 months. Dike and Mbah (1992) reported the efficacy of lemon grass products in protecting cowpea grains stored for two months and inferred that at the three concentrations studied (5.0g, 10.0g and 20.0g per 100g cowpea seed), lemon grass stem and leaf powders significantly protected cowpea grains from damage by C. maculatus though, cowpea grains treated with the former were less damaged when compared with the latter.

Although, the efficacy of Hyptis spicigera (Lam.) leaves in protecting stored cowpea has been documented (Lambert et al., 1985), yet, the effectiveness of similar species, H. suaveolens (Poit) in this experiment relative to other plant products was disappointing. The low levels of sample used as well as the reduction in the strong repellent odour of the powder over-time may have contributed to the reduced effectiveness of this plant material.

#### 4.5. THE EFFECT OF PLANT POWDERS AND ACTELIC DUST ON PERCENTAGE WEIGHT LOSS CAUSED BY C. MACULATUS IN COWPEA STORED FOR 12 WEEKS.

The effect of plant powders and actellic dust on percentage loss in weight of cowpea seeds stored for 12 weeks are shown in Table 9. The ANOVA (Appendix 9) shows that there

Table 9: Effect of plant powders and actellic dust on percentage weight loss of cowpea seeds at 12 weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	8.98 (3.07bcd)	8.33 (2.87cd)	6.90 (2.70bc)	14.53 (3.66bc)
Neem Seed Powder	2.39 (1.69d)	2.39 (1.69d)	1.16 (1.23c)	10.34 (2.28c)
Lemon Grass Stem Powder	18.86 (4.19a-d)	13.12 (3.62a-d)	12.36 (3.45bc)	19.94 (4.31ab)
Garlic Bulb Powder	33.40 (5.81a)	30.64 (5.49ab)	12.13 (3.53abc)	27.90 (5.20a)
Orange Peel Powder	31.23 (5.36ab)	29.42 (5.19abc)	19.96 (4.21ab)	29.01 (5.18a)
Eucalyptus Leaf Powder	17.56 (4.23abc)	8.48 (2.96cd)	6.13 (2.57bc)	16.90 (3.93ab)
African Curry Leaf Powder	8.72 (2.97cd)	6.76 (2.58d)	6.19 (2.37bc)	14.27 (3.47bc)
Hyptis Leaf Powder	13.11 (3.67a-d)	10.99 (3.30bcd)	8.89 (3.06bc)	17.10 (4.0ab)
Neem Leaf Powder	17.12 (4.17a-d)	13.64 (3.75a-d)	10.82 (3.36bc)	19.25 (4.31ab)
Onion Leaf Powder	17.62 (4.22abc)	16.04 (4.06a-d)	14.20 (3.78ab)	20.82 (4.51ab)
Control (0.0)	35.42 (5.98a)	35.42 (5.98a)	35.42 (5.98a)	- -
LSD x DMRF (0.01)	2.52	2.52	2.52	1.40
Concentration Means	3.94b	3.55b	3.03b	5.98a (Control)
LSD (P<0.01)	1.44	1.44	1.44	1.44

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

were significant differences ( $P < 0.01$ ) in weight loss between treatments, concentrations and the control. The neem seed powder at all the three concentrations significantly ( $P < 0.01$ ) reduced the percentage weight loss of cowpea caused by C. maculatus during the 12 weeks storage period. The percentage weight losses of cowpea treated with NSP at the three concentrations were 2.39, 2.39, and 1.16%, respectively. African curry leaf powder was next to NSP in reducing weight loss in cowpea as weight losses at the three levels were 8.72, 6.76 and 6.19%, respectively. Actellic dust followed next with 8.98, 8.33 and 6.90% at low, medium and highest levels respectively and so on. Table 9 also reveals a similar pattern of decrease in the amount of cowpea weight loss due to C. maculatus attack as the concentration of treatment powders is increased. However, the loss in weight of cowpea between some concentrations within a treatment did not differ significantly. The correlation between percentage infestation and percentage weight loss (Appendix II) due to C. maculatus attack was not significant. The percentage reduction in cowpea weights in all the treatments could be attributed to a similar reduction in degree of infestation of the grains. Nevertheless, other factors such as moisture loss in cowpea during the 12 weeks storage period may also play an important role in reducing grain weight.

4.6. **EFFECT OF PLANT POWDERS AND ACTELIC DUST  
ON THE VIABILITY OF TREATED COWPEA STORED FOR  
12 WEEKS**

Table 10 shows the effect of plant powders and actellic dust on percentage viability of cowpea grains after 12 weeks of storage. All the protectants had no significant adverse effect on the viability of cowpea seeds after 12 weeks of storage. The differences in the percentage viability between the treatment levels and the control were highly significant ( $P < 0.01$ ) but insignificant ( $P > 0.01$ ) within the treatments (Appendix 10).

Cowpea treated with neem seed powder exhibited a 100% germination at the three concentrations followed by grains treated with actellic dust (91.67%, 93.33, 96.67%).

Other plant powders which showed significant percentage germination of treated cowpea seeds at various concentration include HLP (90.0-93.33%), LGSP (88.0-91.65%), NLP (88.35-91.65%) and ACLP (86.67-93.33%). Cowpea germination rate for the control was 28.35%.

Cowpea treated with garlic bulb powder had the lowest percentage germination (61.65%) at the lowest concentration compared to the other treatment levels but recorded one of the highest percentage germination (95.0%) at the highest concentration due to low bruchid damage (38.67%). There was a progressive increase in viability of cowpea seeds as the concentration of the materials is increased. However, high germination percentages had been obtained using lemon grass

Table 10: Effect of plant powders and actellic dust on percentage viability of cowpea seeds at 12 weeks post treatment.

Treatments	Concentration (grams) per 100 grams of Cowpea Seeds (wt/wt)			Chemical Means
	2.5g	5.0g	10.0g	
Actellic Dust**	91.67 (9.59a)	93.33 (9.67a)	96.67 (9.86a)	77.50 (8.43a)
Neem Seed Powder	100.0 (10.02a)	100.0 (10.02a)	100.0 (10.02a)	82.08 (8.67a)
Lemon Grass Stem Powder	88.33 (9.40a)	91.67 (9.60a)	91.67 (9.59a)	75.0 (8.30a)
Garlic Bulb Powder	61.67 (7.82ab)	66.67 (8.19ab)	95.0 (9.77a)	62.92 (7.59a)
Orange Peel Powder	65.0 (7.97ab)	76.67 (8.72ab)	80.0 (8.88ab)	62.50 (7.54a)
Eucalyptus Leaf Powder	88.33 (9.42a)	90.0 (9.50a)	91.67 (9.59a)	74.58 (8.27a)
African Curry Leaf Powder	86.67 (9.33a)	88.33 (9.42a)	93.33 (9.68a)	74.17 (8.26a)
Hyptis Leaf Powder	90.0 (9.51a)	91.67 (9.59a)	93.33 (9.68a)	75.83 (8.34a)
Neem Leaf Powder	88.33 (9.41a)	90.0 (9.50a)	93.33 (9.68a)	75.0 (8.30a)
Onion Leaf Powder	81.67 (8.97a)	83.33 (9.13a)	88.33 (9.38a)	70.42 (8.02a)
Control (0.0)	28.33 (4.59b)	28.33 (4.59b)	28.33 (4.59b)	- -
LSD x DMRF (0.01)	4.33	4.33	4.33	2.48
Concentration Means	(9.14a)	(9.33a)	(9.61a)	(4.59b) (Control)
LSD (P<0.01)	2.47	2.47	2.47	2.47

\*\* Concentration of Actellic dust (g): 1.0, 2.0 and 3.0

\* Means followed by the same letter(s) in a column are not significantly different at 1.0% level.

\* Figures in parenthesis are transformed (square root) from original data.

\* Horizontal comparison made for concentration means.

\* Number of seeds used = 20

products (Dike and Mbah, 1992); neem seed oil (Das and Karim 1986); neem seed powder and oil (Usman, 1991), pirimiphos methyl (Taylor and Evans, 1980; Caswell and Akibu, 1980). Other treatments with lower germination percentage (although higher than the control) included Onion leaf powder (81.67, 83.35, 88.33%) and orange peel powder (65.0, 76.67, 80.0%) for low, middle and highest concentrations in that order. The apparent poor performance observed in cowpea seeds treated with garlic bulb, Onion leaf, orange peels, was probably due to low concentration of the materials used. In addition, the hygroscopic nature as well as reduction in the strong aromatic fragrance of some of the powders (e.g garlic) overtime may have affected their potency and therefore loss of protection of cowpea seeds.

However, this experiment has shown that NSP, ACLP, LGSP, AD, ELP and GBP (at the appropriate level) can be used to protect stored cowpea grains against *C. maculatus* for 12 weeks without loss of viability.

#### 4.7. EFFECT OF PLANT POWDERS AND ACTELIC DUST ON QUALITY OF COWPEA GRAINS AFTER 12 WEEKS OF STORAGE

The effect of various plant powders and actellic dust on grain quality after 12 weeks of storage is varied between the protectants and their concentrations.

The quality aspects of the grain under consideration include grain colour (degree of mouldiness or taintiness or freshness), texture (pittiness when touched) and evidence of

Table 11: The effect of plant powders and acetic acid on quality (colour, texture and palatability) of cowpea grains after 12 weeks of storage.

Treatment Level	Conc. (g)	Grain Quality Ratings (Colour & Texture.)					Overall assessment	Grain Taste/Flavour ratings					Overall Assessment
		V. Poor	Poor	Fair	Good	V. Good		Poor	Fair	Good	Overall Assessment		
Control	0.0	9	-	1	-	-	V. Poor	9	1	-	-	-	Poor
Acetic Acid	1.0	-	-	2	6	2	Good	4	6	-	-	-	Fair
	2.0	-	-	1	3	6	V. Good	2	2	6	-	-	Good
	3.0	-	-	-	6	4	Good	5	2	3	-	-	Poor
Neem Seed Powder	2.5	-	-	-	-	10	V. Good	-	-	8	-	-	Good
	5.0	-	-	-	-	10	V. Good	-	8	2	-	-	Fair
	10.0	-	-	8	2	-	Fair	10	-	-	-	-	Poor
Lemon Grass Stem Powder	2.5	-	-	8	2	-	Fair	7	-	3	-	-	Poor
	5.0	-	-	2	8	-	Good	1	7	2	-	-	Fair
	10.0	-	1	-	6	3	Good	2	3	5	-	-	Good
Garlic Bulb Powder	2.5	-	10	-	-	-	Poor	8	2	-	-	-	Poor
	5.0	-	1	9	-	-	Fair	2	8	-	-	-	Fair
	10.0	-	2	2	6	-	Good	-	-	10	-	-	Good
Orange Peel Powder	2.5	10	-	-	-	-	V. Poor	7	3	-	-	-	Poor
	5.0	7	2	1	-	-	V. Poor	3	7	-	-	-	Fair
	10.0	1	2	7	-	-	Fair	-	10	-	-	-	Fair
Eucalyptus Leaf Powder	2.5	-	1	6	3	-	Fair	2	5	3	-	-	Fair
	5.0	1	1	8	-	-	Fair	3	7	-	-	-	Fair
	10.0	-	-	4	6	-	Good	1	4	5	-	-	Good
African Curry Leaf Powder	2.5	-	-	-	7	3	Good	-	9	1	-	-	Fair
	5.0	-	-	-	2	8	V. Good	-	2	8	-	-	Good
	10.0	-	-	-	2	8	V. Good	-	1	9	-	-	Good

Table 11: cond. The effect of plant powders and acetic acid dust on quality (colour, texture and palatability) of cowpea grains after 12 weeks of storage.

Treatment Level	Conc. (g)	Grain Quality Ratings (Colour & Texture)						Grain Taste/Flavour ratings				Overall Assessment
		V. Poor	Poor	Fair	Good	V. Good	Overall assessment	Poor	Fair	Good		
Hyptis Leaf Powder	2.5	6	4	-	-	-	V. Poor	8	2	-	Poor	
	5.0	1	2	7	-	-	Fair	4	5	1	Fair	
	10.0	-	4	6	-	-	Fair	1	6	3	Fair	
Neem Leaf Powder	2.5	-	10	-	-	-	Poor	6	4	-	Poor	
	5.0	-	2	5	3	-	Fair	-	1	9	Good	
	10.0	-	-	6	4	-	Fair	7	2	1	Poor	
Onion Leaf Powder	2.5	9	1	1	-	-	V. Poor	7	3	-	Poor	
	5.0	6	3	1	-	-	V. Poor	-	6	4	Fair	
	10.0	-	4	6	-	-	Fair	1	9	-	Fair	

\* Quantity of Cowpea used = 300 g each.

\* Number of Respondents = 10.

any change in taste of the cooked grains. These conditions of the grains determine market appeal and consumer acceptability of the produce.

The results indicated that cowpea seeds treated with NSP, AD at lower concentrations and ACLP, GBP, LGSP, ELP at higher concentrations had good quality grains (Table 11) as they remained fresh without any evidence of discoloration or pitting. Poor quality grains due to heavy infestation by bruchid were observed in NLP, OPP, HLP and ONLP treated grains particularly at lower concentration, similar to the control. These grains caved in when pressed between two fingers and there was evidence of mouldiness in them.

On grain palatability (Table 11) seeds treated with ACLP, GBP, LGSP, ELP at the highest concentration and NSP, AD at the middle concentration showed no retention of the product's characteristic odour (flavour) after cooking. Grains observed to have "poor" ratings in palatability assessment similar to the control (check) were those treated with ONLP, HLP, OPP and NLP particularly at lower concentrations.

NSP and AD at the highest concentration (10.0g and 3.0g per 100g cowpea seed respectively) imparted a bitter taste to the meal, probably due to the presence of high concentration of their active principles in the grains. Therefore, for acceptability, the concentration of neem seed products and actellic dust may not exceed the middle course. Ivbijaro (1990) and Niber (1995) reported that neem seed oil had bitter taste and smell contrary to the findings of Ogunwolu

and Odunlami (1996). Dike and Mbah (1992), Dike and Mshelia (1996) reported that lemon grass and Eucalyptus products respectively had no deleterious effects on the seed coat colour, texture and palatability of treated cowpea grains after eight weeks of storage, similar, to the findings in this study.

## CHAPTER FIVE

## 5.0 SUMMARY AND CONCLUSION

The major storage pest of cowpea is the bruchid, Callosobruchus maculatus. Losses of stored cowpea due to these beetles in northern Nigeria alone is estimated at over 37 per cent. Viability of the grains is drastically reduced when three or more beetles feed in a seed.

A number of measures are being taken to curb bruchid menace on stored cowpea. Application of synthetic insecticides (for example, Actellic dust) is by and large the commonest and quickest method of achieving control. However, the use of these insecticides, though, effective, possibly results in problems of harmful residues, pest resistance and resurgence. In addition, synthetic insecticides are very expensive, and readily available at the critical period of need. This has therefore made it more expedient to explore local alternatives to synthetic insecticides.

Phytochemical and inert substances (like ash and sand) are being screened to control bruchid in stored cowpea. In this trial, plant materials used were powders of neem seeds and leaves, lemon-grass stems, garlic bulbs, African curry leaves, African bush tea leaves (Hyptis sp), orange peels, Eucalyptus and onion leaves. Actellic dust was used as a check. The trial was conducted in the storage entomological laboratory of Crop Protection Department, Institute for Agricultural Research, Ahmadu Bello University, Samaru-Zaria.

The results on percentage mortality of bruchid in 24 hours showed that the highest mortality (100%) was achieved on cowpea treated with the highest amount of actellic dust and thus performed better than the plant materials as a fast knock down insecticide. However, this concentration (3.0g w/w) is a unit higher than the recommended dosage (2.0g w/w). Whether this marginal increase in protection of cowpea would justify the cost of additional unit of actellic dust over the recommended dosage was not established. However, the higher dosage is likely to increase residue problem and may not appeal to the consumer as observed in this study.

In comparing the plant powders, it was observed that the highest bruchid mortality (65.0%) within 24 hours occurred in cowpea treated with the highest concentration (10.0 g per 100 g cowpea seed) of African curry leaf powder. This was followed by neem seed powder (46.67 per cent); Eucalyptus leaf powder (46.65 per cent). The lowest bruchid mortality (1.67 per cent) within the same period was recorded in cowpea treated with the lowest amount (2.5g w/w) of African bush tea leaf (Hyptis sp.) powder. The mode of action of these botanicals in effecting the observed high mortality of C. maculatus within a short time (24 hours) in treated cowpea seeds is suggested to be biochemical rather than physical since it is known that the active components of some of these phytochemicals affect certain vital physiological systems of the insect.

This situation was different at 48 hours post treatment

where neem seed powder performed better than African curry leaf powder by recording 93.33 per cent bruchid mortality as against 80.0 per cent for the latter, at the same concentration (10.0g w/w). The lowest mortality (15.0 per cent) within 48 hours was observed on cowpea treated with African bush tea and neem leaf powders, each at the lowest concentration (2.5g w/w). The result further indicates that as the quantity of materials is increased, the percentage bruchid mortality also increased. Throughout these periods (24 and 48 hours) there was no mortality observed in the control. The ANOVA tables (Appendix 1-3) show that the differences between the treatments and the control on one hand and amongst the treatments on the other were highly significant ( $P < 0.01$ ).

In conclusion, it has been shown in this study that Actellic dust, African curry leaf, neem seed, garlic bulb, Eucalyptus leaf and lemon grass stem powders can be used to achieve high mortality of C. maculatus within 48 hours (which reportedly is the peak of oviposition) mainly at the highest concentration. Some workers had also recorded high mortality rate of C. maculatus at the highest concentration of plant materials used. However, the relative ineffectiveness of orange peel, African bush tea, neem leaf and Onion leaf powders to ensure high mortality of cowpea beetles within this period could be attributed to low levels of the powders used, and partly due to the volatilization of the active principles particularly in garlic, lemon-grass and Eucalyptus, (which may

be in small amount in the plants) during the drying and grinding processes of the materials.

On oviposition and progeny control, neem seed powder, gave the highest control followed by actellic dust, African curry leaf, lemon grass stem, neem leaf and garlic bulb powders. 100 percent inhibition of adult beetle population build-up was achieved at the highest level of neem seed powder applied probably due to infertility of the eggs laid by the parental females. The nature of the sterilizing effect of neem seed powder on bruchid eggs is not known. However, this particular mode of action of neem product offers great prospects for the management of cowpea bruchids in third world countries. The findings showed that actellic dust, neem seed, African curry leaf, garlic bulb, Eucalyptus leaf, lemon grass stem and neem leaf powders can effectively reduce oviposition and progeny emergence of bruchids on treated grains thereby protecting seeds from heavy damage. Thus, the application of these plant powders at the appropriate concentrations (5.0g and 10.0g w/w) gave highly significant decreases in the number of eggs laid as well as on the emergence of progenies.

The result of the percentage grain damage by bruchid showed that the lowest grain damage (0.0%) and weight loss were recorded on cowpea treated with the highest level of neem seed powder. Similarly, the highest grain damage and weight loss were observed on garlic bulb (72.0%) and Orange peel powders (31.23%), respectively, both at the lowest

concentration. A similar trend of decreasing level of damage and weight loss were observed as the amount of plant powders increased. The apparent poor performance of garlic bulb and lemon grass stem powders relative to neem seed and African curry leaf powders with regard to these parameters may be attributed to the caking nature of their powders which resulted in loss of potency over time. Onion leaf powder performed least amongst the plant powders in all the parameters investigated but was better than the control.

Seed viability was not adversely affected by the treatments. The result showed that neem seed powder at all levels gave 100 per cent seed germination when compared with actellic dust (96.67 per cent), African curry leaf, neem leaf and African bush tea powders each with 93.33 per cent germination at the highest level after a period of three months storage. Other plant powders with over 90 per cent germination at similar level (10.0g w/w) included lemon grass stem, garlic bulb and Eucalyptus leaf powders. However, onion leaf and orange peel powders recorded less than 90 percent germination. The control had only 28.35 percent grain viability showing a great deal of damage of the seeds.

On grain quality and taste, the seeds were largely unaffected by the materials applied. However, some grain samples were rated as poor at some treatment levels either due to slight coating of the grain testa by oil films from the plant material (e.g neem seed), damage of the grains or

flavour emanating from chemical constituents of the materials (e.g neem products and actellic dust). Onion leaf powder treated cowpea had poor taste similar to the control due to heavy insect damage.

In the light of the above findings, it is evident that some materials (e.g NSP, AD, and ACLP) are better than others (e.g LGSP, GBP, ELP, NLP, OPP, ABTP (Hyptis sp) and ONLP) for control of bruchid on stored cowpea. For some plant materials, application of plant powders at levels between 5.0g and 10.0g w/w would be effective to control cowpea bruchid while higher doses may be required for others (e.g GBP, ABTP, LGSP, ELP, etc). Thus, it is suggested that experiments with higher levels of powders be conducted to establish the optimum rates of application of these materials. However, increasing the weights of these powders for possible effectiveness may lead to an increase in the weight of the cowpea bag beyond 100 kg which may hinder consumer acceptability of the treated cowpea. Furthermore, since, some powders performed better than or as well as the synthetic insecticide (actellic dust), which is more expensive, unavailable at critical periods and which may also pose a health hazard to animals, efforts should be made to exploit these botanicals and to adopt the technology for seed dressing purposes for the benefit of the rural farmers and the entire population at large. The powders investigated in this study are unlikely to pose any health hazard in view of their ethno-medicinal importance. Considering the present

prices of synthetic insecticides, application of botanicals to cowpea for storage would be less expensive prophylactic measure for control of C. maculatus and probably other storage insect pests of crops. The results obtained in this trial should stimulate further interest in the search for and screening of other natural plant products with insecticidal potentials with the ultimate aim of isolating, identifying and extracting the active principles for formulation of low-cost botanically based pesticides.

In the savanna region of Nigeria where these investigations were carried out, all the plant materials are readily available in large quantities and are cheap, which make them suitable for low-input agriculture practised by small-scale farmers.

## R E F E R E N C E S

- Abdulkareem, A. (1981). Neem as an antifeedant for certain Phytophagous insects and a Bruchid on Pulses. In natural pesticides from the Neem Tree (Azadirachta indica A. JUSS). Proceeding of the first International Neem Conference Rottach - Egern, W. Germany. 16-18 June 1980. pp.223-249.
- Abivardi, C. (1977). Effect of camphor on embryonic and post-embryonic development of Callosobruchus chinensis L. Journal of Economic Entomology 70(6): 818-820.
- Adebayo, T.A. and Gbolade, A.A. (1994). Protection of Stored Copwea from C. maculatus F. using plant products. Insect Science and Its Application 15, (2): 185-189.
- Adesiyun, A. A. (1973). Storage of Cereals in Northern States of Nigeria. A paper presented at the African Groundnuts Council on Storage and Handling of Groundnuts at Lugard Hall Kaduna on 4th April, 1973. p7.
- Adhikary, S. (1981). The Togo experience in moving from Neem Research to its practical application for plant protection. In Natural Pesticides from the Neem Tree (Azadirachta indica A. Juss). Proceedings of the first International Neem Conference, Rottach-Egern, West Germany, 16-18 June, 1980. pp. 215-222.
- Agina, S. E. and Sani, T. (1995). Studies on the use of peels of orange (Citrus sinensis (L.) Osbeck), queen of the night (Cestrum nocturnum L. and African Curry (Ocimum gratissimum L.) plants as insecticides and repellants. A paper presented at the seventh Annual Conference of the Botanical Society of Nigeria at the National Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria. 3-7 September, 1995. p. 24.
- Ahmed, S. and Koppel, B. (1985). Plant extracts for pest control; Village level processing and use by limited resource farmers. Paper presented at the Association of American Agricultural Scientists Annual meeting in Los Angeles, May, 26-31, 1985.

- Ajayi, O., Arokoyo, J., T. Nezan, J. T., Olayinka, O. O. Ndirmbula, B. M. and Kannike, O. A. (1987). Laboratory assessment of the efficacy of some local plant materials for the control of storage insect pests. Samaru Journal of Agricultural Research 5. (1 and 2): 81-86.
- Akibu, S., Nezan, J. T., Ajayi, O. and Arokoyo, J. T. (1984). A preliminary study of the use of locally plant derived materials in the control of storage pests. NAERLS Newsletter 10 (1): 11-14.
- Ali, S. T., Singh, O. P. and Misra, U. S. (1983). Effectiveness of plant oils against pulse beetle, Callosobruchus chinensis Linn. Indian Journal of Entomology 45:6-9.
- Anonymous (1955). Eucalypts for planting. F. A. O. (UN), Italy 460 PP.
- Anonymous (1968). Food Composition table for use in Africa. FAO/HEW. U.S. Department of Health, Education and Welfare Rome, Italy. 306 pp.
- Anonymous (1990). Annual Report (1989/80) of Agricultural Products Monitoring and Evaluation Unit of the Federal Ministry of Agriculture, Lagos, Nigeria.
- Anonymous (1992). Neem: A Tree to solving Global Problems. National Academy Press, Washington 186pp.
- Anonymous (1962). Cowpea Transit Problems. West African Stored Products Research Unit. Annual Report. Published by Federal Ministry of Commerce and Industry, Lagos, Nigeria.
- Arctander, S. (1960). Perfume and Flavour Materials of Natural Origin. Elizabeth, New Jersey, USA pp252-354.
- Arnborg, T. (1982). Trees for Shelter Belt Establishments in the Dry Savanna Zones of Nigeria. A paper presented at a Seminar in the Faculty of Agriculture University of Sokoto, Sokoto, Nigeria. 6th October, 1982. 10pp.

- Ayedokun, A. O. (1988). Insect pest and disease control in leguminous crops. Proceedings of National Crop Protection. Paper presented at the Institute for Agricultural Research and Training Obafemi Awolowo University, Moor Plantation, Ibadan, Nigeria. March, 22-25, 1988, p 38-65.
- Babu, T. R., Reddy, V. S. and Hussain, S. H. (1989). Effect of Edible and non-edible oils on the development of the Pulse beetle, Callosobruchus chinensis (L) and on viability and yield of Mungbean. Tropical Science 29(3):215-220.
- Bastos, J. A. M. (1974). Control of the cowpea weevil, Callosobruchus maculatus (Fab. 1992) with methyl bromide. Turrialba, 24(2): 230232. 1974: In Cowpeas: Abstract of World Literature, Volume 3: 303.
- Bastos, J. A. M. and Aguiar, P. A. A. (1971). Control of the Cowpea weevil, Callosobruchus maculatus (Fab.) {Coleoptera: Bruchidae} with Phostoxin. Cowpeas. Abstract of World Literature. 1974-1980; 3:303.
- Booker, R. H. (1965). List of insects found in association with Cowpea at Samaru. Samaru Miscellaneous Paper 9: 4pp.
- Booker, R. H. (1967). Observations on three Bruchids associated with Cowpeas in Northern Nigeria. Journal of Stored Products Research. 3:1-15.
- Booth, S. A 1976). Cowpea Storage. Samaru Conference Paper November 8:11pp.
- Bottimer, L. J. (1968): Notes on Bruchidae of America, North of Mexico with a list of World Genera. Canadian Entomology 100: 1009-1049.
- Bruno, J. C., Cristini, R. B. and Gokithin, A. (1966). Essence of Eucalyptus citriodora and its composition. Review of Faculty Farm Bioquim 4(1):119-136.
- Burr, H. K., Kon, S. and Morris, H. J. (1968). Cooking rates of dry beans as influenced by moisture content, temperature and time of storage. Food Technology 22(3): 88-90.

- Caswell, G. H. (1960). Observations on abnormal form of Callosobruchus maculatus (Fab.) Bulletin of Entomological Research 50(4): 671-674.
- Caswell, G. H. (1968). The storage of Cowpea in the Northern States of Nigeria. Proceedings of the Agricultural Society of Nigeria p.4-6.
- Caswell, G. H. (1980): A review of work done in the Entomological section of the Institute for Agricultural Research on the pests of stored grain. Samaru Miscellaneous Paper 13
- Caswell, G. H. and Akibu, S. (1980). The use of pirimiphos methyl to control bruchids attacking selected varieties of stored cowpeas. Tropical Grain Legume Bulletin. 17/18:9-11.
- Cavallito, C. J., Buck, J. S. and Suter, C. M. (1944). Garlic and its Constitutents Journal of American Chemical Society. 66:1952-1954.
- Chipeta, F. M. and Roberts, M. J. (1974). A preliminary evaluation of storage methods for cowpeas. Research Bulletin: Bunda College of Agriculture 5:59-61.
- Cobbinah, J. R. and Appiah-Kwarteng (1989). Effects of some neem products on stored maize weevil, Sitophilus zeamais Motsch. Insect Science and its Application 10(1):89-92.
- Cornes, M. A. (1964). A revised listing of insects associated with stored products in Nigeria. Annual Report, Nigerian Stored Products Research Institute (1964), p. 96-116.
- Credland, P. F. and Dick, K. M. (1987). Food consumptions by larvae of three strains of the cowpea seed beetles, Callosobruchus maculatus (Fab.). Journal of Stored Products Research 23(1): 31-40.
- Das, G. P. (1987). Efficacy of neem seed oil on the egg and grub mortality of Callosobruchus chinensis L. (Coleoptera: Bruchidae). Tropical Grain Legume Bulletin. 34:14-15.
- Das, G. P. and Karim, M. A. (1986). Effectiveness of neem seed kernel oil as surface protectant against the pulse, beetle, Callosobruchus chinensis L. (Coleoptera: Bruchidae). Tropical Grain Legume

Bulletin 33:30-38.

- Dike, M. C. and Akibu, S. (1997). Cowpea Storage pests and their management. Nigerian Journal of Agricultural Extension (in press).
- Dike, M. C. and Mbah, O. I. (1992). Evaluation of Lemon grass (Cymbopogon citratus Staph.) products in the control of Callosobruchus maculatus Fab. (Coleoptera: Bruchidae) on stored Cowpea. Nigerian Journal of Plant Protection 14:88-91.
- Dike, M.C. and Mshelia. G.B. (1997). Laboratory Assessment of the efficacy of Eucalyptus leaf and stem powders in the control of Callosobruchus maculatus (Fab.) on stored cowpea. Samaru Journal of Agricultural Research Vol. 13. 1996.
- Dobie, P., Hainses, C. P., Hodges, R. J. and Prevett, P. F. (1984). Insects and Arachnids of Tropical Stored Products: Their Biology and Identification. Storage Department, Tropical Development and Research Institute, London, 272pp.
- Don Pedro, K. N. (1989). Mode of action of fixed oils against eggs of Callosobruchus maculatus (F.). Pesticide Science: 26(2):107-115.
- Duncan, D. B. (1955). Multiple Range and Multiple F-tests. Biometrics. 11:1-42.
- Dyte, C. E and Blackman, D. G. (1970). The Spread of insecticide resistance in Tribolium castaneum (Herbst) (Coleoptera: Tenebrionidae). Journal of Stored Products Research 6:255-261.
- El-Sawaf, S. K. (1956). Some factors affecting the longevity, Oviposition, and rate of development in the Southern Cowpea weevil, Callosobruchus maculatus (Fab.) (Coleoptera: Bruchidae). Bulletin of Entomological Society, Egypt. 40:29-95.
- Egwuatu, R. I. (1987). Current Status of conventional insecticides in the management of stored product pests in the tropics. Insect Science and its Application. 8(4/5/6): 695-701.
- Ezedinma, F. O. C. (1961). Research on Cowpea (Vigna Sp.). In Nigeria before 1960: Federal Department of Agricultural Research, Ibadan. Memo. 68:1-3.

- Evans, S. V., Gatehouse, A. M. R., and Fellows, L. E. (1985). Detrimental effects of 2, 5-dihydroxy-methyl-3, 4- dihydroxy pyrrolidine in some tropical legume-seeds on larvae of Callosobruchus maculatus (Fab.) Cowpeas Abstract of World Literature. 1983-1985, pp. 118.
- Faris, D. G. (1965). The origin and evolution of cultivated forms of Vigna sinensis. Canadian Journal of Genetics and Cytology. 7:433-452.
- Fry, J. S. (1938). Neem leaves as an insecticide. Gold-Coast Farmer. 190pp.
- Gbolade, A.A. and Adebayo, T.A. (1993). Fumigant effects of some volatile oils on fecundity and adult emergence of Callosobruchus maculatus F. Insect Science and Its Application Vol. 14, No. 516, pp 631-636, 1993
- Grainge, M., Ahmed, S., Mitchell, W. C. and Hylin, J. W. (1985). Plant species reportedly possessing pest control properties- an East-West-Centre/University of Hawaii data base-Resource Systems Institute, East-West-Centre, Honolulu, College of Tropical Agriculture and Human Resources, University of Hawaii.
- Guenther, E. (1964). The Essential Oils. Volume 3. D. Van Nostrand Company, Inc., London. pp.400-433.
- GTZ (1980). Post Harvest Problems. Documentation of an OAU/GTZ, Seminar, Lome, March 1980.
- Handmarsh, P. S., Tyler, P. S. and Webley, D. J. (1978). Conserving grain on small farms in the tropics. Outlook on Agriculture 9:214-219.
- Henkel, R. (1987). The Neem Tree: a farmer's friend. The Furrow Valley Edition. May/June, 1987. John Deere & Co. 92(3):25.
- Hill, D. S. and Waller, J. M. (1990). Pests and Diseases of Tropical Crops. Volume 1. Principles and Methods of Control. Intermediate Tropical Agriculture Series. Longman, London, and New York. Pp. 175.
- Howe, R. W. (1978). Introduction: The Principles and Problems of storage and Pest Control. Outlook on Agriculture 9:198-203.

- IITA, (1984). Research Highlights. International Institute for Tropical Agriculture, Ibadan, Nigeria.
- IITA, (1985). Research Highlights. International Institute for Tropical Agriculture, Ibadan, Nigeria.
- Illo, H. A. (1987). Comparative efficacy of neem products in the control of rust-red flour beetle, Tribolium sp. on stored groundnuts. HND Thesis, College of Agriculture, Ahmadu Bello University, Zaria.
- Ishaya, A. T. (1989). Effect of palm oil and groundnut oil dosages on oviposition and longevity of the bean weevil, Callosobruchus maculatus (F) B.Sc Project Report Faculty of Agriculture, Ahmadu Bello University, Zaria. 85pp.
- Ivbijaro, M. F. (1983a). Preservation of cowpea, Vigna unguiculata (L) Walp. with the neem seed, Azadirachta indica A. Juss. Protection Ecology 5:177-182.
- Ivbijaro, M. F. (1983b). Toxicity of neem seed, Azadirachta indica A. Juss to Sitophilus oryzae (L.) in stored maize. Protection Ecology 5:353-357.
- Ivbijaro, M. F. (1984a). Toxicity effects of Groundnut oil on the rice weevil, Sitophilus oryzae (L.) Insect Science and its Application 5(4):251-252.
- Ivbijaro, M. F. (1984b). Groundnut oil as a protectant of maize from damage by the maize weevil, Sitophilus zeamais Motsch. Protection Ecology. 6:267-270.
- Ivbijaro, M. F. (1987). Prospects for Neem in Nigerian Agriculture. Proceedings of third International Neem Conference, Nairobi. pp.525-533.
- Ivbijaro, M. F. (1990). The Efficacy of seed oils of Azadirachta indica A. Juss and Piper guineense Schum and Thorn on the control of Callosobruchus maculatus F. Insect Science and its Application 11(2): 149-152.

- Ivbijaro M. F. and Agbaje, M. (1986). Insecticidal activities of Piper guineense Schum and Thorn, and Capsicum species on the cowpea beetle, Callosobruchus maculatus. Insect Science and its Application 7 (4):521-524.
- Jacobson, M. A. (1975). Insecticides from plants. A review of the literatures, 1954-1971. U. S. D.A. Handbook, 461 U.S., Washington, 136 pp.
- Jacobson, M. A. (1981). Neem Research in the U. S. D.A: Chemical, Biological and Cultural aspects. Natural pesticides from the Neem Tree, (Azadirachta indica A. Juss). Proceedings First International Neem Conference Rottach-Egern, W. Germany, June, 1980. P.215-222.
- Jacobson, M. A. (1983). Control of stored product insects with phytochemicals. Third International working Conference on stored-products-Entomology. October 23-28, 1983, Manhattan, Kansas, U. S. A.
- Jayasingh, D. B. (1986). Admixture of inert dusts to cowpea seeds to prevent insect infestation. Food storage and Infestation Division, Ministry of Industry and Commerce, Jamaica.
- Jilani, G. and Malik, M. M. (1973). Studies on neem plant as repellent against Stored-grain insects. Pakistani Journal of Science and Industrial Research 16:251-254.
- Jilani, G Saxena, R. C. and Rueda, B. P. (1988). Repellent and growth-inhibiting effects of tumeric oil, Sweet flag oil, neem oil and "Margosan-O" on Red-Rust flour beetle (Coleoptera: Tenebrionidae). Journal of Economic Entomology. 81(4):1226-1230.
- Jotwani, M. G. and Sircar, P. (1965). Neem seed as a protectant against grain pests infesting wheat seed. Indian Journal of Entomology 27:160-164.
- Jotwani, M. G. and Sircar, P. (1967). Neem seed as a protectant against the bruchid, Callosobruchus maculatus (Fab.) infesting some leguminous seeds. Indian Journal of Entomology 29(1):21-24.
- Kelly, S. (1969). The Eucalypts. In G. M. Chippendale and R. D. Johnston. Thomas Nelson Publication Ltd. (Australia) 1969.

- Ketkar, C. M. (1976). Utilization of Neem (Azadirachta indica A. Juss) and its by-products. Modified Neem Cake Manurial Project, Bombay, India: Khadi and Village Industrial Commission.
- Kousou, D. K. (1989). Evaluation des differents produits du Neem (Azadirachta indica, A. Juss.) pour le contro le de Sitophilus zeamais (Motsch) sur le en postrecolte. Insect Science and its Application 10 (3): 365-372.
- Kranz, J., Schmutterer, H. and Koch, W. (1977). Diseases, Pests and Weeds in Tropical Crops. John Wiley and Sons, London, 590pp.
- Kraus, W., Cramer, C., Bokel, M. and Sawitzki, G (1981). New Insect antifeedant from Azadirachta indica and Melia zedarach. In Natural Pesticides from the Neem Tree, Proceeding of First International Neem Conference, Germany. p.53-62.
- Krista, C., Shellie, D. and Bliss, F. A. (1990). Genetic improvement of food quality factors in Common Beans. In Research for Crop Improvement. A Van Schoonhoven and O. Voyses (Eds).
- Kritchevsky, D. (1991). The effect of dietary garlic on the development of Cardiovascular disease. Trends in Food Science and Technology 2(6): 141-143.
- Ladd, T. L. (1981). Neem seed Extracts as feeding Deterrents for the Japanese Beetle, Popillia japonica. In Natural pesticides from the Neem Tree. Proceedings of First International Neem Conference, Germany, p.149-159.
- Lale, N.E.S. (1994). Effectiveness and persistent effects of spices on cowpea bruchid and maize weevil. Samaru Journal of Agricultural Research, Vol. 11: 79-84.
- Lale, N.E.S. and Ajayi, F.A. (1996). Comparative effects of extraction solvents on the persistence and acute toxicity of seed extracts against the cowpea bruchid, Callosobruchus maculatus F. Samaru Journal of Agricultural Research, vol. 13, 49 - 55.
- Lambert, J. D. H., Gale, J., Arnason, J. T., and Philogene, B. J. (1985). Bruchid Control with traditionally used insecticidal plants, Hyptis spicigera and Cassia nigricans. Insect Science and its Application 6(2): 167-170.

- Luna, J. M. and House, G. J. (1990). Pest Management in sustainable agricultural system (Ames. I. A: Soil and water conservation society) p. 157-173.
- Matsumura, F. (1975). Toxicity of Insecticides. Plenum Press, New York 503pp.
- Mejule, F. O. (1974). An investigation into insecticidal effects of Capsicum. Nigerian Stored Products Research Institute p. 89-90.
- Meinwald, J. G., Prestwich, D., Nakanishi, K. and Kubo, I. (1978). Chemical ecology: Studies from East Africa. Interdisciplinary Studies at ICIPE laboratories in Nairobi are yielding exciting chemical results. Science 199:1167-1173. In Warthen, J. D. (1979).
- Meisner, J., Ascher, K. R. S. and Aly, R. (1981). The Residual effect of some products of Neem seeds, on larvae of Spodoptera littoralis in laboratory and field trials. In Natural pesticides from the Neem Tree. Proceedings First International Neem Conference, Germany (1980) p. 157-170.
- Mital, H. C. (1971). Protection of Cowpeas from insect infestation with the aid of fixed oils. Journal of West African Science Association 16:45-48.
- Morgan, E. D. (1981). Strategy in the isolation of insect control substance from plants. In Natural Pesticides from the Neem Tree. Proceedings First International Neem Conference, Rottach-Egern, Germany. p.43-52.
- Morris, H. J. and Wood, E. (1956). Influence of moisture control on keeping quality of dry beans. Food Technology. 10:225-229.
- Nasseh, M. O. (1980). Studies on the insecticidal activities of Allium sativum L. for the control of various stages of Epilachna varivestis Muls. (Coleoptera: Coccinelidae). Zoologie Angewandte Entomologie. 92:464-471.
- Naik, R. L. and Dumbre, R. B. (1984). Effect of some vegetable oils used in protecting stored cowpea on biology of pulse beetle, Callosobruchus maculatus (Fab.). (Coleoptera: Bruchidae). Bulletin of Grain Technology 22(1):25-32.

- Nezan, J. T., (1983). The use of local materials (Pepper, Ash, and Oil) to control storage pests on sorghum, millet, cowpea, groundnut and maize. HND Project Dessertation College of Agriculture, Ahmadu Bello University, Zaria, Nigeria.
- Niber, B.T. (1995). The protectant and toxicity effects of four plant species on stored maized against Prostephanus truncatus (Horn) (Coleoptera:Bostrichidae. Tropical Science 35: 371-375.
- Nwanze, K. F. and Horber, E. (1975). How seed size affects the occurrence of "active" and "miniature" forms of Callosobruchus maculatus in laboratory populations. Environmental Entomology 4:729-732.
- Ogunwolu, E.O. and Odunlami, A.T. (1996). Suppression of seed bruchid (Callosobruchus maculatus) development and damage on cowpea (Vigna unguiculata) with Zanthoxylum zanthoxyloides (Rutaceae) root bark powder when compared to neem seed powder and pirimiphos-methyl. Crop Protection 15: 603-607.
- Okeke, B. O. (1986). Bionomics and control of the groundnut bruchid, Caryedon serratus (Olv.). M.Sc. Thesis, Ahmadu Bello University, Zaria, Nigeria. 121 pp.
- Olaifa, J. I. and Akingbohunge, A. E. (1986). Antifeedant and insecticidal effects of the passive extracts of Azadirachta indica, Petiveria alliacea and Piper guineense on the variegated grass hopper, Zonocerus variegatus (Orthoptera: Pyrgomorphidae). Proceedings Third International Neem Conference, Nairobi, Kenya.
- Olaifa, J. I. and Erhun, W. O. (1988). Laboratory evaluation of Piper guineense for the protection of cowpea against Callosobruchus maculatus F. Insect Science and its Application 9(1):55-59.
- Olaifa, J. I., Erhun, W. O. and Akingbohunge, A. E. (1987). Insecticidal activities of some Nigerian plants. Insect Science and its Application. 8(2):221-224.
- Olayide, S. O. (1972). A quantitative analysis of requirements, supplies and demands in Nigeria, 1968-1975. Federal Department of Agriculture, Lagos. 56 pp.

- Olufade, A. O. (1985). Plants used in traditional storage. Paper presented at the 1985 National Agricultural Extension and Research Liaison Services, Crop Protection Workshop held at NAERLS, A. B. U., Zaira, Nigeria. December, 10th -12th, 1985. 7pp.
- Olufade, A.O. (1987). Food crop storage methods. Paper presented at the 1987 National Agricultural Extension and Research Liaison Services, Crop Protection Workshop, A.B.U., Zaria, Nigeria: December, 1-3, 1987
- Onu, I. and Sulyman, A. (1997). Effect of powdered peels of citrus fruits on damage by Callosobruchus maculatus (F.) to cowpea seeds. Journal of Sustainable Agriculture, 9 (4): 85-92.
- Onu, I and Aliyu, M. (1995). Evaluation of powdered fruits of four peppers (Capsicum spp.) for the control of Callosobruchus maculatus (F.) on stored cowpea seed. International Journal of Pest Management, 41(3): 143-145.
- Osuji, F.N.C. (1985). Outlines of stored products Entomology for the Tropics. Fourth Dimension Publishers, Enugu, 103 pp.
- Penfold, A. R. and Willis, J. L. (1961). The Eucalyptus: Botany, Cultivation, Chemistry and Utilization. world Crop Series, London. Pp. 360.
- Pereira, J. (1983). The effectiveness of six vegetable oils as protectants of cowpeas and bambara groundnuts against infestation by Callosobruchus maculatus (Fab.). (Coleoptera: Bruchidae). Journal of Stored Products Research 19:57-62.
- Pereira, J. and Wohlgemith, R. (1982). Neem (Azadirachta indica A. Juss.) of West African origin as a protectant of stored maize. Zoologie Angewandte Entomologie 94 (2): 208-214.
- Pixton, S. W. (1967). Moisture Content - its significance and measurement in stored products. Journal of Stored Product Research. 3:35-47.
- Poucher, W. A. (1974). Perfumes, Cosmetics and Soap. Volume 1. Halsted Press, New York, 300 pp.
- Pradhan, S. (1962). In The Neem Tree. National Research Council, U.S.A.

- Pradhan, S. and Jotwani, M. G. (1968). Neem as an Insect deterrent. Chemical Age, India 19:756-760.
- Prakash, A., Pasalu, I. C. and Mathur, K. C. (1980). Save stored paddy from insects. Indian Farming 30:21.
- Pruthi, H. S. (1937): Report of the Imperial Entomology. Scientific Report of Agricultural Institutes, New Delhi, 123 pp.
- Purseglove, J. W. (1974). Tropical Crops: Dicotyledons. Longmans, London, 719 pp.
- Puttarudriah, M. S. and Bhatta, K. L. (1955). A preliminary note on Studies of Mysore plants as sources of insecticides. Indian Journal of Entomology 17:165-174.
- Rachie, K. O. and Rawal, K. M. (1976). Integrated Approaches to improving cowpeas, Vigna unguiculata (L) Walp. International Institute for Tropical Agriculture, Ibadan, Nigeria. 36 pp.
- Rachie, K. O. and Roberts, L. M. (1974). Grain legumes of the lowland and humid tropics. Advances in Agronomy 26:44-61.
- Radwanski, S. A. (1981). Multiple land utilization in the tropics. An integrated approach with proposals for an International Neem Research and Development Programme. In Natural Pesticides from Neem Tree. Proceeding, First International Neem Conference, Rottach-Egern, 1980. Germany. p. 267-278.
- Raheja, A. K. (1976). Assessment of losses caused by insect pests to cowpea in northern Nigeria. PANS 22:229-233.
- Raheja, A. K. (1986). Problems and Prospects of cowpea production in Nigerian Savannas. Tropical Grain Legume Bulletin. 32:78-87.
- Rahman, M. and Yadav, T. D. (1985). Efficiency of delta-methrin, cypermethrin, permethrin and fenvalerate dusts against development of Callosobruchus maculatus (F.) and C. chinensis (L.). Indian Journal of Entomology 47:30-37.
- Redden, R. (1983). The inheritance of seed resistance to Callosobruchus maculatus (Fab.) in cowpea, (Vigna unguiculata (L.) Walp). II. Analysis of percentage

- emergence and emergence period of bruchids in the F4 seed generation of two reciprocal crosses. Australian Journal of Agricultural Research 34:697-705.
- Redknap, R. S. (1981). The use of crushed Neem berries in the control of some insect pests in Gambia. In Natural Pesticides from Neem Tree. Proceedings First International Neem Conference, Germany. p. 205-214.
- Robins, S. R. J. (1983). Selected markets for the essential oils of Lemon-grass, Citronella and Eucalyptus. Tropical Products Institute. London. 17 pp.
- Ruscoe, L. N. E. (1972). Studies on insect growth regulatory effects of Azadirachtin on cabbage white butterfly (Pieris brassicae) and Cotton Stainer (Dysdercus fasciatus). In: The Neem Tree. National Research Council, U.S.A.
- Sano, I. (1967). Density effect and environmental temperature as the factors producing the active form of Callosobruchus maculatus (Fab.). (Coleoptera: Bruchidae). Journal of Stored Product Research 2(3):187-195.
- Saxena, R. C. (1987). Antifeedants in tropical pest management. Insect Science and its Application 8(4/5/6): 731-736.
- Schmutterer, H. (1981). Ten years of Neem Research in the Federal Republic of Germany. In Natural Pesticides from the Neem Tree (Azadirachta indica A. Juss). Proceedings First International Neem Conference, Rottach. Egern, Germany, 16-18 June, 1980. P.21-32.
- Schmutterer, H. (1990). Properties and potentials of natural pesticides from the Neem tree (Azadirachta indica A. Juss). Annual Review of Entomology. 35:271-297.
- Schmutterer, H. and Ascher, K.R.S. (1984). Natural Pesticides from the Neem tree and other tropical plants. Proceedings, Second International Neem Conference Rottach-Egern, Germany, 25-28 May, 1983.

- Schmutterer, A., Ascher, K.R.S. and Rembold, H. (1982). Natural Pesticides from the Neem tree (*Azadirachta indica* A. Juss). Proceedings, First International Neem Conference Rottach-Egern, Germany, 16-18 June, 1980.
- Schoonhoven, L.M. (1981). Perception of Azadirachtin by some lepidopterous larvae. In Natural Pesticides from the Neem tree (*Azadirachta indica* A. Juss.) Proceedings First International Neem Conference, Rottach-Egern, Germany, 16-18 June, 1980.
- Schoonhoven, A.V. and Hill, N. (1981). Effectiveness of vegetable oil fractions in controlling the Red Mexican bean weevil on stored beans. Journal of Economic Entomology, 74:478-479.
- Siddiq, S.A. (1981). Efficacy and Persistency of powdered Neem seeds for treatment of stored wheat against *Trogoderma granarium*. In Natural Pesticides from the Neem. Proceedings, First International Neem Conference. Germany, p.251-258.
- Singh, S.R. and Jackai, L.E.N. (1985). Insect Pests of Cowpeas in Africa. Their life cycle, economic importance and potential for control. In Cowpea Research, Production and Utilization (Edited by Singh, S.R. and Rachie, K.O.), p.217-232, John Wiley and Sons, Chichester, USA.
- Singh, S.R., Luse, A.R., Leuschner, K. and Managju, D. (1977), Groundnut oil treatment for the control of *C. maculatus* during Cowpea Storage. Journal of stored Products Research. 14:77-80.
- Southgate, B.J., Howe, R.W. and Brett, B.A. (1957), The Specific status of *Callosobruchus maculatus* (Fab.) and *C. analis* (Fab.) Bulletin of Entomological Research 48:79-89
- Sowunmi, O.E. and Akinnusi, O.A. (1983). Studies on the use of Neem Kernel in the control of stored cowpea beetle (*Callosobruchus maculatus* F.). Tropical Grain Legume Bulletin 27:28-31.
- Sowunmi, O.E. and Fetuga, B.L. (1982). Loss of pirimiphos methyl applied to stored cowpea under tropical conditions. Tropical Grain Legume Bulletin. 24:16-17.

- Srivastava, S., Gupta, K.C. and Agrawal, A. (1988). Effect of plant product on Callosobruchus chinensis L. infestation on redgram. Seed Research 16(1):98-101 [En.5 ref] Department of Food and Nutrition, G.B. Pant University of Agriculture and Technology, Pantnager 263845, India 66pp.
- Stoll, G. (1988). Natural Crop Protection in the Tropics. AGRECOL, OKOZENTRUM, CH-4438, LANGENBRUCK, Switzerland, 188pp.
- Su, C.H.F., (1977). Insecticidal properties of black pepper to rice weevils and cowpea weevils. Journal of Economic Entomology 70:18-21.
- Su, C.H.F., Roy, D.S. and Patrick, G.M. (1972). Toxicity of citrus oils to several stored products insects. Laboratory Evaluation. Journal of Economic Entomology. 65(5):1438-1441.
- Taylor, T.A. (1970). On the incidence of active form of Callosobruchus maculatus (Fab.) on mature cowpea in the field. Nigerian Entomological Magazine 2:66-69.
- Taylor, T.A. (1974). Observations on the effects of initial population densities in culture and humidity on the population of "active" females of Callosobruchus maculatus (Fab.). (Coleoptera: Bruchidae) Journal of Stored Products Research 10(2):113-123.
- Taylor, T.A. (1975). Effect of Orange and Grape fruit-peels on Callosobruchus maculatus (Fab.) infestation of Cowpea. Ghana Journal of Agricultural Science 8(2):169-172.
- Taylor, T.A. and Agbaje, L.A. (1974). Flight activity in normal and active forms of Callosobruchus maculatus (F) in a store in Nigeria. Journal of Stored Products Research 10(1):9-16.
- Taylor, T.A. and Aludo, J.I.S. (1974). A further note on the incidence of "active" females of Callosobruchus maculatus (F.) on mature cowpea in the field in Nigeria. Journal of Stored Products Research 10(2):123-125.
- Taylor, T.A. and Evans, N.J. (1980). Laboratory evaluation of pirimiphos methyl and permethrin dilute dusts for control of bruchid beetles attacking stored pulse. International Pest Control-September/October, 1980 Issue.

- Tiwari, B.K., Bajpal, V.N. and Agrawal, P.N. (1966). Evaluation of insecticidal, fumigant and repellent properties of lemon grass oil. Indian Journal of Experimental Biology 4:120.
- Tun, S.B. (1979). Control of Cowpea Storage Pests and life history of the cowpea weevil, Samaru Miscellaneous paper. 83:2-12.
- Usman, S.A.M. (1991). Evaluation of Neem Products and synthetic insecticides in the control of Rust-redflour beetle, Tribolium castaneum (Herbst). (Coleoptera: Tenebrionidae) on Stored groundnuts M.Sc. Thesis, A.B.U., Zaria, Nigeria 104pp.
- Utida, S. (1954). "Phase" dimorphism observed in the laboratory population of the cowpea weevil, Callosobruchus maculatus (Fab). Japan Journal of Zoology 18:161-168.
- Utida, S. (1965). "Phase" Dimorphism observed in the laboratory population of the cowpea weevil, Callosobruchus maculatus (Fab) 4: The mechanism of induction of the flight form. Japan Journal of Ecology 15(5):193-198.
- Utida, S. (1968). The influence of the parental condition on the production of the flight form in population of Callosobruchus maculatus (Fab.) Japan Journal of Ecology 18:246-249.
- Utida, S. (1969). Photoperiod as a factor inducing the flight form in the population of southern cowpea weevil, Callosobruchus maculatus (Fab.) Japan Journal of Applied Entomological Zoology 13(3):129-134.
- Utida, S. (1972). Density dependent Polymorphism in the adult of Callosobruchus maculatus (Fab.) (Coleoptera: Bruchidae). Journal of Stored Products Research 8:111-126.
- Utida, S. and Takahashi, F. (1958). Phase dimorphism observed in the laboratory population of the cowpea weevil, Callosobruchus maculatus (F.): chemical differences of body constituents between two phases. Japan Journal of Applied Entomological Zoology. 2(1):33-37.

- Vietmeyer, N.D. (1992). Neem: a tree for solving global problems. Report of an ad hoc panel of the Board of Science and Technology for International Development, National Research Council, Washington, D.C. U.S.A., National Academy Press, 141 pp.
- Warthen, J.D. Jr (1979). Azadirachta indica A. Juss. A source of insect feeding inhibitors and growth regulators. Agriculture Review and Newsletter. North Eastern Series U.S.D.A. No. 4. 21pp.
- Watt, J.M. and Breyer, B. (1962). The medicinal and poisonous plants of southern and eastern Africa. E. & S. Livingstone, Ltd., Edinburgh and London 345pp.
- William, J.O. (1980). Notes on Bruchidae associated with stored products in Nigeria. Tropical Grain Legumes Bulletin 21:5-10
- Yadav, T.D. (1973). Studies on the insecticidal treatment against bruchids, Callosobruchus maculatus (Fab.) and C. chinensis (L.) damaging stored leguminous seeds. In Saxena, R.C. 1987.
- Yepsen, R.B. Jr., (1976). Organic Plant Protection. Rodale press, U.S.A. 78pp.
- Zainab, A. (1986). Pharmacognostical studies of some local plants of cosmetic value with special reference to Eucalyptus species: M.Sc. Thesis A.B.U., Zaria, Nigeria.106 pp.
- Zanno, P.R., Miura, E., Nahanishi, K. and Elder, D.L. (1975). Structure of the insect phago-repellent Azadirachtin. Applications of PRTF/CWD-13 nuclear magnetic resonance. Journal of American Chemical Society. 97:1975-1977.

Appendix 1: Analysis of variance for the effect of plant powders and actellic dust on mortality of adult C. maculatus Fab. within 24 hours post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	463.085	154.362	92.465**
Chemicals	9	313.287	34.810	20.852**
Levels x Chemicals	27	111.067	4.114	2.464**
Residual	78	130.214	1.669	
Total	117	1017.653		

\*\* Highly significant

Appendix 2: Analysis of variance for the effect of plant powders and actellic dust on mortality of adult C. maculatus within 48 hours post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	917.248	305.749	282.361*
Chemicals	9	168.503	18.723	17.290**
Levels x Chemicals	27	260.291	9.640	8.903**
Residual	78	84.461	1.083	
Total	117	1435.543		

\*\* Highly significant

Appendix 3: Analysis of variance for the effect of plant powders and actellic dust on mortality of Adult C. maculatus within seven days post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	72.161	24.054	163.739**
Chemicals	9	527.447	58.605	398.941**
Levels of Chemicals	27	175.816	6.512	44.327**
Residual	78	11.458	0.1469	
Total	117	786.701		

\*\* Highly significant

Appendix 4: Analysis of variance for the effect of plant powders and actellic dust on oviposition of C. maculatus at 15 days post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	942728.9	314243.0	503.022**
Chemicals	9	39699.2	4411.0	7.061**
Levels x Chemicals	27	17794.9	659.1	1.055 <sup>NS</sup>
Residual	78	48727.4	624.7	
Total	117	1048950.4		

\*\* Highly significant

NS = Not Significant (P>0.01).

Appendix 5: Analysis of variance for the effect of plant powders and actellic dust on F1 progeny development of C. maculatus at four weeks post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	125.955	41.985	66.638**
Chemicals	9	308.663	34.296	54.434**
Levels x Chemicals	27	114.966	4.258	6.758**
Residual	78	49.143	0.630	
Total	117	598.727		

\*\* Highly significant

Appendix 6: Analysis of variance for the effect of plant powders and actellic dust on F2 progeny development of C. maculatus at eight weeks post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	2337.104	779.035	128.596**
Chemicals	9	516.672	57.408	9.476**
Levels x Chemicals	27	192.102	7.115	1.174 NS
Residual	78	472.524	6.058	
Total	117	3518.403		

\*\* Highly significant

NS = Not significant

Appendix 7: Analysis of variance for the effect of plant powders and actellic dust on F3 progeny development of C. maculatus at 12 weeks post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	2722.486	907.495	239.149**
Chemicals	9	1293.270	143.697	37.868**
Levels x Chemicals	27	554.722	20.545	5.414**
Residual	78	295.986	3.795	
Total	117	4866.463		

\*\* Highly significant

Appendix 8: Analysis of variance for the effect of plant powders and actellic dust on percentage cowpea damage by C. maculatus after 12 weeks post treatment.

Source of Variation	DF	SS	MS	F
Levels	3	189.437	63.146	26.537**
Chemicals	9	275.899	30.655	12.883**
Levels x Chemicals	27	99.805	3.696	1.553 <sup>NS</sup>
Residual	78	185.602	2.380	
Total	117	750.743		

\*\* Highly Significant

NS = Not Significant (P>0.01).

Appendix 9: Analysis of variance for the effect of plant powders and actellic dust on percentage loss in weight of grains after 12 weeks of treatment.

Source of Variation	DF	SS	MS	F
Levels	3	134.144	44.715	53.081**
Chemicals	9	79.013	8.779	10.422**
Levels x Chemicals	27	20.224	0.749	0.889 <sup>NS</sup>
Residual	78	65.706	0.842	
Total	117	299.087		

\*\* Highly significant

NS = Not Significant at  $P > 0.01$  or  $P > 0.05$ .

Appendix 10: Analysis of variance for the effect of plant powders and actellic dust on grains viability after 12 weeks of treatment.

Source of Variation	DF	SS	MS	F
Levels	3	516.134	172.045	69.236**
Chemicals	9	13.754	1.528	0.615 <sup>NS</sup>
Levels x Chemicals	27	9.944	0.368	0.148 <sup>NS</sup>
Residual	78	193.822	2.485	
Total	117	733.654		

\*\* Highly significant

NS = Not Significant at  $P > 0.01$  or  $P > 0.05$ .

Appendix 11: CORRELATION MATRIX  
Degree of Freedom = 118

Parameters	MORTALITY											Wt/los	Viab
	24 Hrs	48 Hrs	7th day	Ovipos	F1	F2	F3	Cowp Dam	Wt/los	Viab			
Mort. 24 HRS	1.0000												
Mort. 48 HRS	0.2468	1.0000											
Mort. 7th day	-0.9878	-0.4522	1.0000										
Ovip.	-0.6223	-0.6664	0.3959	1.0000									
F1 Emerg.	-0.6096	-0.6679	0.3502	0.9752	1.0000								
F2 Emerg.	-0.5075	-0.5665	0.3644	0.8616	0.8332	1.0000							
F3 Emerg.	-0.5350	-0.5779	0.4042	0.8748	0.8577	0.8603	1.0000						
Cowpea Damage	-0.5985	-0.5170	0.5807	0.6736	0.6288	0.5245	0.6567	1.0000					
Weight loss	0.6042	0.5856	-0.5040	-0.8364	-0.8043	-0.8058	-0.8228	-0.6774	1.0000				
Viabil.(seed)	0.5344	0.6126	-0.3724	-0.9151	-0.8797	-0.9310	-0.8441	-0.5774	0.8748	1.0000			

Appendix 12: Determination of moisture contents of various plant materials used in the trials.

S/No	Materials	Wet Weight (g)	Oven Dried Weight (g)	% M.C.	Average M.C. (%)
1.	Eucalyptus Leaf Powder	12.85	12.60	1.95)	2.13
		13.00	12.70	2.31)	
2.	Lemon Grass Stem Powder	33.45	32.20	3.74)	3.38
		28.15	27.30	3.02)	
3.	Neem Seed Kernel Powder	18.60	18.25	1.88)	2.03
		18.40	18.00	2.17)	
4.	Neem Leaf Powder	8.60	8.40	2.33)	2.46
		8.50	8.28	2.59)	
5.	<u>Hyptis</u> sp. Leaf Powder	6.40	6.05	5.63)	4.94
		5.90	5.65	4.24)	
6.	<u>Ocimum</u> sp. Leaf Powder	6.51	6.45	0.92)	1.83
		7.30	7.10	2.74)	
7.	Garlic Bulbs Powder	106.90	47.35	55.71)	56.09
		107.02	46.60	56.46)	
8.	Orange Peel Powder	15.52	15.15	2.38)	2.98
		15.40	14.85	3.57)	
9.	Onion Leaf Powder	86.80	8.35	9.74)	9.68
		105.70	10.30	9.62)	
10.	Sampea-7 (Cowpea Seeds)	93.54	88.80	5.070	5.47
		89.40	84.15	5.87)	

Appendix 13: Average Monthly Laboratory temperatures and Relative Humidity From January to December, 1995 and 1996

<u>Temperature Average</u>			<u>R/Humidity</u>
<u>Months/Year</u>	<u>Min<sup>°C</sup></u>	<u>Max<sup>°C</sup></u>	<u>Average %</u>
Jan., '95	10.5	28.2	26.30
Feb.	13.3	30.5	24.05
Mar.	18.4	35.8	28.05
Apr.	19.4	36.2	36.10
May.	17.0	34.2	56.25
Jun.	15.6	31.4	60.80
Jul.	21.7	29.8	72.0
Aug.	20.1	28.7	79.0
Sep.	20.4	29.9	75.55
Oct.	19.0	32.0	64.45
Nov.	15.6	28.4	40.35
Dec.	<u>14.1</u>	<u>32.8</u>	<u>20.85</u>
Average	17.06 <sup>°C</sup>	31.49 <sup>°C</sup>	48.65%

<u>Temperature Average</u>			<u>R/Humidity Average</u>
<u>Months/Year</u>	<u>Min<sup>°C</sup></u>	<u>Max<sup>°C</sup></u>	<u>%</u>
Jan., '96	10.3	32.3	20.05
Feb.	17.0	33.4	20.35
Mar.	20.8	37.7	31.20
Apr.	23.0	27.4	43.75
May.	21.8	34.2	58.40
Jun.	19.5	30.2	70.05
Jul.	19.0	27.7	69.95
Aug.	20.8	27.7	80.85
Sep.	19.0	30.1	75.55
Oct.	18.5	31.4	60.30
Nov.	13.1	30.5	23.35
Dec.	11.7	32.6	16.85
Average	17.88 <sup>°C</sup>	31.27 <sup>°C</sup>	47.55%