CHAPTER 1

REVIEW OF LITERATURE
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DISTRIBUTION

Roesli and Subramanyam, (2002) noted the red-legged ham beetle (RLHB; *Necrobia rufipes*), a pest of stored products such as copra, ham, cheese, dried fish, and other protein-rich foods. *N. rufipes* infests various commercially important stored commodities in Nigeria and the development of *N. rufipes* on several commodities (dried fish, copra, cacao beans, palm kernels, groundnuts, and maize) were studied (Osuji, 1977). Development was completed in dried fish (where it was most rapid), palm kernels, groundnuts, and copra but not in cacao beans or maize. Occurrence of *N. rufipes* damaging cashew nut was recorded by Pratissoli (1997). In a survey of godowns in Kerala, India, *N. rufipes* and *O. surinamensis* were found to be the most important pests (Kumari et al., 1992). Investigations on insect pests of stored oil-palm kernels (Allotey and Kumar, 1989) established the value of *N. rufipes* as a predator. *N. rufipes* was also found in a museum infesting the crevices and spongy parts of the bones of a recently prepared skeleton of a whale at Kozhikode, Kerala. (Adolph and Soans, 1969).

A survey in the market in Ibadan, Nigeria in the period from January 1971 to July 1972 showed that Coleoptera, especially *Dermestes maculatus* (which accounted for 71.5% of the observed infestation) and *N. rufipes* (28.0%), infested a high proportion of the dried fish sold. Although both species were abundant throughout the year, infestation was highest in the hot dry months and lowest in the rainy ones. *Tribolium castaneum* and *Trogoderma granarium* were found in considerable numbers. (Osuji, 1974 a).
The insect fauna on stored palm produce was studied in Nigeria in a transit shed (Allotey, 1988). The pooper search method revealed individuals of the clerid *N. rufipes* throughout the year, despite fumigation with phostoxin (aluminium phosphide).

When samples of dried fish of the genera viz. *Citharinus, Clarias, Heterotis* and *Synodontis* on sale in the market in Ibadan, were examined the numbers of examples of *D. maculatus* and *N. rufipes* found per 100 g fish averaged 6.4 (1.53), 59.5 (24.5), 33.7 (19.2) and 29.5 (9.65), respectively. The lipid contents of the samples averaged 12.29, 16.64, 12.87, and 13.42%, for the four genera respectively (Osuji, 1974b).

**BIOLGOGY**

Preliminary observations on the biology of the *N. rufipes* were carried out by Simmons and Ellington (1925). They made some observations on the biology and behaviour of *N. rufipes* and gave general accounts on the eggs, hatching, larvae, pupae and adults and also discussed some life history information such as oviposition, incubation period, fecundity, developmental period, pupal period etc. The fecundity was an average of 137 eggs and the incubation period was reported to be 4-5 days.

The development of *D. maculatus* in dried fish was studied under uncontrolled laboratory conditions in Nigeria (Osuji, 1975d). Females laid eggs within 12 h of copulation, and oviposition was improved by the presence of free water. Hatching occurred about 48 h after oviposition. Larval development was completed in 33.5 days, during which seven moults occurred and a body length of 14 mm was attained. It was also observed that crowding prolonged larval life. When intact pieces of fish were available, the last-instar larva bored into one of them and pupated within the hardened larval skin, but when ground fish was provided, a quiescent pre-pupal stage was
observed. The adult emerged about 11 days after the end of the last larval instar, irrespective of the mode of pupation.

Investigations were made on the biology of *Typhaea stercorea*, *N. rufipes*, *Attagenus simulans* and *A. augustatus*. *Typhaea stercorea*, of which the larvae feed on the germ and the adults on the endosperm of the grain, had two generations a year and overwintered as an adult. *N. rufipes* had one generation per year, the adults likewise overwintering. Both larvae and adults fed on the germ of grain with moisture content of 12% and over. The larvae of *A. simulans* and *A. augustatus*, but not the adults, were injurious to grain (Ya, 1970).

Studies on varietal preference, growth and development of pests *N. rufipes* and *Orizaephilus surinamensis* in stored copra (Kumari and Mamman, 1998) revealed that the severity of infestation varied with varieties and the growth index varied with respect to larval period, larval mortality, pupal period, pupal mortality, adult emergence, adult longevity, and fecundity.

A comparative assessment of the biological performance of *D. maculatus* in various dietary media namely dried fish, fish meal, bone meal, palm kernel meal, blood meal, and whole meal has been made (Osuji, 1978) and the dried fish followed by fish meal was found to be significantly superior to the commercial feeds. He suggested that the greater suitability of the dried fish diet for the development and biological performance of the beetle might be attributable to its superior nutritional composition in respect of crude proteins, total lipids, and water content, among other factors.

Elbert (1978) studied the biology of *Trogoderma variabile* including the development and diapause of larvae. The results indicated that development of *T. variabile* in unheated room is possible. Because of the very
slow development at lower temperatures economically important damages are unlikely.

Some aspects of the life patterns of *D. maculatus* and *Dermestes lardarius*, had been described by Schmidt (1974). He observed that the beetles and larvae consumed mainly pure fats or food substances with fatty components. The hair like sense organs in the antennae was used for the reception of smell.

Bhuiyan and Saifullah (1997) studied some aspects of the biology of *N. rufipes* using a mixture of dried fish and copra as food. The average longevity of adults was found to be 60.64 ±39.46 days for females and 49.42 ±18.2 days for males. The mean fecundity recorded was 89.7±17.8 eggs with arrange of 0-350 eggs per female. The hatchability was 89.59±7.27 percentages. Egg lying continued until the death of the female.

Azab *et al.*, (1973 a) studied the biology of *D. maculatus* in Egypt. When reared in the laboratory on dried meat, 5-6 overlapping generations developed in a year. Both males and females paired several times, and the females laid their eggs singly or in groups of up to 25. Adult males and females lived for up to 189 and 178 days, respectively in autumn (21.5°C). The sex ratio was 1:1.

Nath and Pande (1996) examined the biology of *D. maculatus* under uncontrolled laboratory conditions on dried fish in north –east India. Pre-oviposition, oviposition and post-oviposition periods lasted for 5 to 6 days , 40 to 47 days, and 8 to 10 days, respectively. The fecundity varied from 29 to 95 and spectacularly improved by the addition of wet cotton. The egg stage lasted for 36 to 48 hours. Larvae underwent 7 instars and the development was completed in 25 to 30 days. Larval duration was prolonged by crowding.
Pupation took place in the crevices of the fish body and lasted for 5 to 7 days. Adults were long-lived and polygamous.

Cordingley (1980) discussed the general biology of *Phalaenoides glycine* including rates of development at different temperatures. The optimum temperature range for larval development was 15-27°C and threshold 10.1°C approximately.

**EFFECT OF TEMPERATURE AND HUMIDITY ON DEVELOPMENT AND FECUNDITY**

Toye (1970) studied the humidity and temperature reactions of adult *D. maculatus* Deg. with reference to infestation on dried fish and was found to have stronger preference than larvae for the higher humidity.

In an investigation on the development, fecundity and longevity of *Demestes ater* at various combinations of temperature and humidity, the last larvae and adults were found to avoid a temperature range of 30-45°C. Longevity recorded a maximum of 100 days at 25°C and the fecundity was very variable (0-135) as was the percentage hatch (0-69 %) (Coombs, 1981).

Both *Dermestes haemorrhoidalis* and *D. peruvianus* (Coombs, 1979) developed at all humidities tested at 25°C and the rate of oviposition found to be diminishing with age of female.

Howe (1953) observed that relative humidity has a marked effect than temperature on the development of *Dermestes frischii*. Pupal period was shortest at 37°C.

Life cycle of *Dermestes lardarius* was completed in 223 days at 17.5 and 20°C, but at 30°C it took only 55 days. Temperature had a great influence on the number of eggs laid. The total yield of eggs reached a peak of 1261 at 20°C and then declined to 52 at 27.5. No eggs were laid at 30°C. Optimal
temperature for egg laying in the species was found to be 20ºC (Jacob and Fleming, 1984 a).

An investigation in to the effect of illumination intensity on the response of the hide beetle, *D. maculatus*, to aggregation pheromone (Rakowski, 1988) revealed that the intensity of light do play an important role in the behaviour of *D. maculatus*.

Larval and pupal development at different moisture levels and on various media were examined (Scoggin and Tauber, 1951) and the results established that when the water content was maintained between 10-15 percentages, larval mortality was lowered and the number of larval instars and duration of larval development decreased, and larger adults emerged.

An inquiry was made in to the effect of temperature and relative humidity upon the development and fecundity of *D. lardarius* (Coombs, 1978) suggested that development of the female *D. lardarius* took longer than that of the males. Shortening of larval period was observed at high humidities. Development was more rapid at higher temperature Unsuccessful pupation was the rule at 15ºC and at 30ºC none of the adult pairs laid eggs. The fertility of the eggs was very variable and only of the order of 50 percentages.

The duration and viability of the egg stage of *D. maculatus* were determined using a wide range of constant temperatures and humidities (Jacob and Fleming, 1985) Temperatures over which the eggs hatched greatly influenced the duration of the egg stage but had little effect on viability, except at the lowest temperatures studied (15 and 17.5ºC). The mean duration of the egg stage varied from about 2 days at 37.5 ºC to up to 17 days at 15ºC. Humidity had little effect on the incubation period except at the lowest
temperatures, but had a marked effect on viability. Viability was highest at 90% R.H and lowest at 20% R.H.

The duration of development, pattern of egg lying, and fecundity of *Dermestes haemorrhoidalis* were investigated on a fishmeal diet at various temperatures and relative humidities (Jacob and Fleming, 1984 b). At 65% R.H., eggs failed to hatch at temperatures below 15 or above 32.5°C; the mean duration of the egg stage varied from 2.6 days at 32.5°C to 11.6 days at 15°C. At 25°C, neither the duration of the egg nor egg viability appeared to be affected by humidities in the range 20-90%. At 65% R.H., there were 6-8 larval instars at 20 and 25°C and 7-9 at 30°C. Humidity also affected the number of instars. The shortest mean larval developmental period was 37.3 days at 30°C, 65% RH., and the longest was 76.0 days at 20°C, 65% R.H. Adults were comparatively long-lived and laid higher numbers of eggs for longer periods at 20°C than at other temperatures. Below 20°C, fewer eggs were laid, and above this temperature adult lifespan and fecundity declined.

The life-span and fecundity of mated pairs of adults of *Dermestes lardarius* were compared at 25°C and 65% R.H. when water was not provided, given once a week, once a day, or supplied continuously. It was found that the moisture content of the food alone did not support adult life for long. Drinking water was required at least once a week to achieve the maximum life span, and was needed more often if females were to be more productive. The longest oviposition periods were obtained when water was provided most often (Jacob and Fleming, 1982).

Thornton (1981) evaluated the effect of temperature on the growth and development of a South African strain of *D. maculatus*. At constant temperatures of 20-35°C, the incubation period averaged 6.7-2.1 days, and the larval, pre-pupal and pupal periods averaged 43.9-20.8, over 10 to 4, and 11.1-6.0 days, respectively. No pupae formed at 20°C. Females kept at 35°C
laid an average of 605 eggs, as compared with 1129-1464 at lower temperatures. Egg mass was inversely related to temperature, averaging 0.33 mg at 20°C and 0.18 mg at 35°C.

Adult females of *D. lardarius* maintained at 27.5°C and 80% R.H. began to lay eggs when 10-21 days old, continued laying for 7-21 days, and laid up to 17 eggs, of which less than 50% hatched. At 20°C and 80% R.H., most females began to lay when 57-101 days old, and produced 14-58 eggs in 14-119 days, about 50% of them fertile. At 25°C and 80% R.H., most females laid some eggs when a few days old; there was then a gap of 14 weeks or more before the rest of the eggs were laid. Lower humidity (65% R.H.) appeared to eliminate early oviposition (Jacob and Fleming, 1981).

Fleming and Jacob (1986) studied the influence of temperature and relative humidity upon the number and duration of larval instars in *D. lardarius*. Under most conditions and, contrary to the findings of other workers, number of instars varied. At 65% R.H., the number of instars increased from the usual 6 at 20°C to 8 at 27.5°C. At 25°C, the number of instars decreased from 8 at 50% R.H. to 6 (for most larvae) at 80% R.H. At 65% R.H., the shortest mean larval development period was 51.5 days (at 27.5°C) and the longest was 109.7 days (at 17.5°C). Mortality was high at 17.5 and above 22.5°C. It was concluded that the optimal conditions for development were 20-22.5°C and 65% R.H.

Larvae of *D. lardarius* were bred at 80% R.H. and 15 or 30°C on a diet of fishmeal, yeast and cholesterol. Adults obtained at 15°C were morphologically normal and lived up to 211 days; most females failed to lay eggs but 2 laid a small number (4 and 12) of infertile eggs after 89 days. At 30°C, adults lived only up to 36 days and none of the females laid eggs. Larvae were also reared at 65% R.H. and 15 or 30°C until they pupated and then they were transferred to 20 and 25°C, respectively. Adults at 25°C lived
up to 61 days but laid no eggs. Adults obtained at 20°C were morphologically normal but very small in size and lived up to 165 days; mating between them was infertile (Jacob and Fleming, 1980 a).

Duration of the egg stage of *D. lardarius* and percentage hatch at various combinations of temperature and relative humidity were examined (Jacob and Fleming, 1980 b). As the temperature increased from 15 to 32.5°C, the duration decreased from 12.9 to 3.0 days and percentage hatch from 50.8 to 12.5. Relative humidity had little effect on either duration or percentage hatch. When eggs were kept only at 25 and 30 °C and 65 and 90% R.H., percentage hatch ranged from 34 to 44.

Study on the biology of the beetle, *D. maculatus* was conducted (Pisfil and Korytkowski, 1974) at 24°C and 70% R.H, fishmeal in the form of powder or pellets being provided as food. The egg stage lasted for an average of 3.4 days, the six larval instars together averaged 21.05 days, the pre-pupal and pupal stages averaged 4.8 and 8.3 days, respectively, and the adult males and females lived for averages of 116.15 and 114.35 days, respectively.

A study was conducted to determine the effects of temperature and humidity on the development of stored products pest, *D. maculatus* (Majeed, 2002). Treatments comprised: 28±2, 32±2 and 38±2°C with 40±5 and 60±5% RH at each level of temperature. Development of adults was more adversely affected by temperature compared to relative humidity. The longest duration of maturation (6.70±0.36 days) was obtained at 28±2°C and 60±5% RH. The shortest duration 4.90±0.97, 23.1±0.72 and 3.70±0.31 days for maturation, oviposition and post-oviposition, respectively, was recorded at 38±2°C and 40±5% RH. An increase in temperature at constant relative humidity affected the development and decreased the maturation, oviposition, post-oviposition and longevity of adults. An increase in relative humidity decreased the rate of maturation, oviposition, post-oviposition and longevity at a particular
temperature. The larval survival percentage decreased with temperature increase. Temperature and relative humidity affected the larval duration and developmental index. However, the larvae developed faster at higher temperatures and lower humidities. Temperature and humidity affected the pupal period and survival. The pupae developed faster at higher temperature and lower humidity.

Azab et al., (1973 b) investigated the effects of temperature, relative humidity and type of food on the duration of the immature stages of *D. maculatus*. At 75% R.H. and 21, 27 or 35°C., the egg stage averaged 5.91, 3.02 and 1.87 days, respectively. At 55°C R.H., the larval stage averaged between 18 days at 35°C and 64 days at 21°C; at 27°C; it averaged 22 days at 75% R.H. and 46 days at 55% R.H., the pupal stage averaged between 4 days at 35°C and 13 days at 21°C; relative humidity appeared to have little effect on the duration of this stage. At 75% R.H., the adults lived for a mean of 169-173 days at 21°C and 49.1-51.9 at 35°C. Adults of both sexes lived longer at 55% than at 75% R.H.

Survey on factors influencing the rate of oviposition in *D. maculatus* (Azab et al., 1973c) revealed that when the relative humidity was 75%, females kept at 21, 27 or 35°C laid average totals of about 214, 362 and 83 eggs each, respectively, and the oviposition period averaged about 130, 92 and 28 days, respectively. At 27°C and 55% R.H., the average total number of eggs laid/female was about 333 and the oviposition period averaged about 86 days. Females oviposited normally only when they had been provided with water in addition to suitable food. To obtain maximum numbers of eggs it was necessary to keep males and females together continuously.

The reactions to temperature of the larvae of *D. maculatus* were studied using a radial temperature gradient apparatus (Osuji, 1975 c). The larvae consistently avoided the hottest zones of the gradients (39.5 or 44°C)
and were preferentially distributed in the cooler zones (23.5-25°C or 32 - 34°C).

Nakahira and Arakawa (2005) studied the effect of photoperiod on development of the green lacewing, *Chrysopa pallens* and found that the larval developmental period was affected by photoperiod.


Nakamura (2003) examined the effect of photoperiod on *Dolycoris baccarum* nymphal development; growth and adult size and found that the developmental period was longer under short rather than a long day photoperiod. Adult size was largest under an intermediate photoperiod of L13: D11, and was smaller under both longer and shorter photoperiods.

Ekesi et al., (1999) studied the effects of temperature and photoperiod on development and oviposition of the legume flower thrips, *Megalurothrips sjostedti* and at constant temperatures, the highest pre-oviposition period was observed at 29°C under a photoperiod of L16:D8. Egg production also ceased at this temperature/photoperiod combination.

At 23-25°C and 80-90 % RH, the oviposition period of *D. maculatus* lasted for up to 73 days and female laid up to 270 eggs each; the larval stage averaged 40 days and the pupal stage 12 days, and the adult life-span 76 days for females and 70 days for males (Shahhosseini, 1980).

Amos and Morley (1971) investigated the longevity of *Dermestes frischii* at two temperatures (30 and 35°C), four relative humidities (30, 45, 60
and 75%) and three salt contents (14, 25 and 60%). At 30°C, the average duration of adult life varied from about 12 days (at the lowest R.H. and high salt content) to nearly 60 days (at high R.H. and no salt content). At 35°C, the effects of humidity and salt content were similar but less marked, and adult life lasted about 12-25 days.

**MATING BEHAVIOUR**

In the oriental beetle, mating and copulation occurred without an obvious complex courtship, but observations of post mating behaviours suggested that mate guarding occurs (Facundo et al., 1999).

Edvardsson and Arnqvist (2005) examined the effect of copulatory courtship on differential allocation in the red flour beetle, *Tribolium castaneum*, which indicated an increase in female oviposition rate in response to intensive leg rubbing but failed to find any support for an effect on sex allocation. The overall sex ratio of offspring was slightly male biased but females did not appear to regulate the sex ratio of their offspring.

Wang et al., (2005) studied the effect of diamond black moth (DBM), *Plutella xylostella* (Lep., Plutellidae) male and female multiple mating on fecundity, fertility, and longevity and found that there were no significant differences in the fecundity, fertility, and longevity between the single and twice mated females. Results suggested that DBM females might be monandrous. Multiple mating did not increase male or female mating fitness.

**DETERRENTS AND ANTIFEEDANTS**

In an investigation into the effects of secondary compounds from tropical plants (*Artocarpus heterophyllus*, *Anacardium occidentale* and *Mimos pudica*) on the diamondback moth (*Plutella xylostella*), Qin-Wei Quan et al., (2004) confirmed the oviposition deterrence and antifeedant
effects in all extracts and observed that the deterrent effect was reduced with time. *A. occidentale* extracts showed continuous oviposition deterrent effect.

Raja *et al.* (2003) analyzed the effects of plant extracts on *Spodoptera litura* (Lepidoptera: Noctuidae) and established that the hexane, diethyl-ether, dichlormethane, ethyl acetate, methanol and aqueous extracts collected from leaves and roots of *Artemisia nilagirica*, and from the leaves of *Acorus calamus, Anisomeles malabarica, Cassia auriculata, Holoptelea integrifolia, Lobelia leschenaultiana, Tarrena asiatica, Pergularia daemia* and *Wedelia calendulacea* showed significant ovicidal, insecticidal and ovipositional deterrent activities.

*Eupatorium odoratum* [Chromolaena odorata] and *Eucalyptus robusta* (JiDong *et al.*, 2002) were found to have the greatest oviposition deterrent effects against *Conopomorpha sinensis*. Oil, methanolic seed extract, acetone leaf extract, aqueous seed extract, chloroform seed extract and petroleum ether seed extract of karanj were evaluated and found to act as oviposition deterrents, antifeedants and larvicides against a wide range of insect pests (Kumar and Singh, 2002).

Evaluation of the effect of celangulim (from *Celastrus angulatus* extracts) on the population dynamics of the diamondback moth *Plutella xylostella* (Ming *et al.*, 2002) confirmed that celangulim strongly deter the adults from laying eggs and significantly inhibit larval feeding.

Studies on extracts of *Rhododendron molle* as oviposition deterrents and ovicides against *Plutella xylostella* (Lepidoptera: Plutellidae) carried out by Hua (2000) proved that it is an effective deterrent and ovicide against *Plutella xylostella*. Evaluation of the comparative efficacy and protectant ability of powdered and ethanolic extracts of *Dennettia tripetala* fruits, root bark, and leaves in suppressing the oviposition and development of
*Callosobruchus maculatus* on stored cowpea revealed that the powdered fruits and bark of *D. tripetala* had ovicidal, larvicidal, and insecticidal effects on *C. maculatus* (Adedire and Lajide, 2000).

Aziz and Ismail (2000) tested the effectiveness of three plant oils (*Nigella* sp. *Nigella sativa*, *Boswellia sacra* and, *Cucurbita maxima*) on the bean bruchids (*Bruchidius incarnates*) and were found to possess repellent, oviposition deterrent and protectant effects.

Elhag *et al.*, (1999) evaluated methanol and diethyl ether extracts of harmal(*Rhazya stricta*), neem seed kernels (*Azadirachta indica*), cloves (*Syzygium aromaticum*), citrus peel and ramram (*Heliotropium bacciferum*) for their deterrence to oviposition by *Callosobruchus maculatus* on chickpeas and found that both extracts of all materials significantly reduced oviposition on treated seeds.

Evaluation of the effect of aqueous extracts of *Trichilia pallida* leaves and twigs on the development and oviposition of *Tuta absoluta* (Thomazini *et al.*, 2000) indicated that the leaf and twig extracts affected insect development, mainly at the larval stage. Methanol extracts of leaves of *Ageratum houstonianum*, *Artemisia brevifolia*, and leaves and drupes of *Melia azedarach*, showed varying degrees of oviposition deterrent effect against *Henosepilachna vigintioctopunctata* (Meena *et al.*, 1998).

Plant products (neem seed kernel powder, neem leaf powder and *Lantana camara* leaf powder and two aromatic oils (*Citronella* and *Palmarosa*) were evaluated against the ground nut bruchid, *Caryedon serratus*, a serious pest of ground nut pods and kernels (Kumari *et al.*, 1998). Citronella oil and palmarosa oil gave total protection to groundnut pods by inhibiting oviposition by the bruchid and among the plant powders, *L. camara*
had a good oviposition deterrent activity, but lost effectiveness gradually after one month.

Out of twelve plant extracts evaluated for their oviposition deterrent properties against khapra beetle, *Trogoderma granarium* (Dwivedi and Kumar, 1999) extracts of *Cassia occidentalis* and *Withania somnifera* were effective oviposition deterrents. A methanol extract of *Momordica charantia* leaves strongly deterred Cucurbitaceous feeding beetle species viz., *Aulacophora femoralis*, *A. nigripennis*, *Epilachna admirabilis*, and *E. boisduvali* from feeding (Abe and Matsuda, 2000).

The plant extracts viz., neem (*Azadirachta indica*), arandi (*Ricinus communis*), and karanj (*Derris indica*) [*Pongamia pinnata*], pilu (*Salvadora oleoides*), marva (*Ocimum basilicum*), amaltas (*Cassia fistula*), bluegum (*Eucalyptus globulus*), guava (*Psidium pyriferum*), dhatura (*Datura metel*), and bougainvillea (*Bougainvillea* sp.) applied to sorghum were evaluated as oviposition deterrents against *Tribolium castaneum*. In general, all plant extracts significantly reduced the oviposition of *T. castaneum* on jowar seeds (Lohra *et al.*, 2001).

Evaluation of the effects of seed treatment and fumigation of artificially infested cowpea with the volatile oil of air-dried leaves of *Ageratum conyzoides* (Asteraceae) (Gbolade *et al.*, 1999) resulted in acute toxicity to adults of the cowpea weevil, *Callosobruchus maculatus*.

The oviposition deterrent and antifeedant activity of 2 formulations containing Neemrich I + oil of *Salvadora oleoides* and Neemrich I + neem extract (Plantmix I and Plantmix II, respectively) were examined against *Phthorimaea operculella* and both the formulations showed oviposition deterrent and antifeedent activity, greater activity than their individual constituents (Sharma *et al.*, 1998).
Acetone extracts of *Cassia occidentalis* and *Croton bonplandianus* and pet-ether extracts of *Verbesina encelioides* and *Cassia occidentalis* were effective in deterring oviposition in *Callosobruchus chinensis* (Maheshwari and Dwivedi, 1997).

Studies were conducted to determine the ovicidal and oviposition deterrent properties of acetone, alcohol, benzene, petroleum ether and distilled water extracts of 10 plant species against *Phthorimaea operculella* (Sharma et al., 1997) and the results indicated that the efficacy of alcohol extracts was superior to that of other solvents in reducing egg hatch and oviposition.

Evaluation of various materials such as horticultural oils, an insecticidal soap, neem, garlic extract, a sugar ester, and a synthetic insect growth regulator (fenoxycarb) for their ability to inhibit *Cacopsylla pyricola* feeding and oviposition (Weissling et al., 1997) indicated that they could be successfully used as oviposition and feeding deterrents.

Spraying the bhendi [okra] crop with various neem products resulted in an oviposition-deterrent effect on females of the pest *Amrasca biguttula biguttula* (Patel and Patel, 1996). Evaluation of some hexane extract of leaf and chloroform extract of seed of *Annona squamosa* as feeding deterrents against adult *Longitarsus nigripennis* (Coleoptera: Chrysomelidae) (Babu et al 1996) showed high feeding deterrence.

Applications of 3 concentration of oil-free neem seed extracts (*Azadirachta indica*) to cabbage plants in cages did not deter oviposition by individuals of 3 species of noctuid moths, *Trichoplusia ni*, *Peridroma saucia* and *Spodoptera litura*. 1% crude oil emulsion significantly reduced the proportion of eggs laid by *S. litura* on treated plants. Sprays consisting of highly processed neem seed extracts, used at concentration that provide larval
control, are unlikely to be generally effective as oviposition deterrents to noctuid pests (Naumann and Isman, 1995).

Dilawari et al., (1994) indicated that the methanolic extract of *Melia azedarach* effectively checked the fecundity and contributed to the mortality at various stages of the life cycle of diamond-back moth, *Plutella xylostella*. Extracts from calyxes of an alternate host plant, *Hibiscus sabdariffa* exhibited antifeedant as well as oviposition-deterrent activities against *Earias vittella* (Dongre and Rahalkar, 1992).

Various neem, *Azadirachta indica* products were compared with copra oil, palm kernel oil and 0.25% diazinon dust for protection of stored maize against the curculionid *Sitophilus zeamais*. Although copra and palm kernel oil reduced attack by *S. zeamais*, these edible oils were not as effective as neem oil (Cobbinah and Kwarteng, 1989).

Ethanolic extracts of seeds of neem (*Azadirachta indica*), *Caropa procera, Lansium domesticum* and *Swietenia macrophylla* were highly active feeding deterrents against the southern corn rootworm, while hexane extracts were ineffective as deterrents. (Landis and Gould, 1989).

Vegetable oils, particularly groundnut and palm oils, are known to be effective in controlling some pests of stored pulses (Golob and Webley 1980). Nigerian fish merchants rub groundnut and other vegetable oils on dried fish for protective or cosmetic reasons (Don- Pedro 1989 and 1990). In Senegal, traders in Dakar retail market coat dried fish with vegetable oil to protect it from insect infestation (Wood 1982). However, results from an experiment in the Lake Turkana region of Kenya, in which bottled cod-liver was applied to dried tilapia (*Oreochromis* sp.) at a treatment level of 44 ml/kg, showed that after 45 days storage there was little difference in insect infestation between treated and untreated samples (Walker and Wood, 1986).
Leatemia and Isman (2004) studied the toxicity and antifeedant activity of crude seed extracts of *Annona squamosa* against the lepidopteran pests viz. diamond-back moth, *Plutella xylostella* and cabbage looper, *Trichoplusia ni*. Crude aqueous extracts deterred feeding of 4th instar *P. xylostella* in a leaf disc choice bioassay. Aqueous seed extracts and aqueous emulsion of ethanolic seed extracts were toxic to both species.

Application of oils (ground nut, traditional coconut, industrial coconut, palm, and shark liver oil) against *Dermestes maculatus* on dried trout (*Salmo gairadnerii*) (Don-Pedro, 1989) significantly reduced the development of progeny of *D. maculatus* only at dosages of 56ml/ kg. When *D. maculatus* eggs were assayed against groundnut oil, freshly applied on dried trout surfaces, the LC 50 value was found to be as low as 18.29/ kg. It was observed that absorption of surface oils by fish muscle over time reduced activity against eggs. Generally, the oils were shown to act mainly against eggs and have no direct toxicity against active stages of the insect.

Natural products from parthenium fed (in artificial diet) to *Heliothis zea* were found to be consistently inhibitory. At a dietary concentration of 3.0-mm/kg fr.wt; tetrneurin-A (a parthenolide) reduced larval growth of *H. zea* by 88% relative to controls in a chronic feeding bioassay (Isman and Rodriguez, 1983).

Using the dry fish weight loss, number of live larvae, number of pupae formed and number of live adults as indices of activity, Adedire and Lajide (2000), suggested that *Piper guineense* and *Dennettia tripetala* possess contact toxicity, fumigant, oviposition inhibition, ovicidal and larvicidal activities against *D. maculatus*.

Treatment of dried Tilapia with 0.25, 0.50, 1, and 2 g of neemseed powder per 25 gm of fish (Okorie *et al.*, 1990) affected the oviposition and
the hatchability of different age group of eggs of *D. maculatus* and also killed the adults. Incubation period was prolonged. Larvae did not develop beyond the 2\(^{nd}\) instar and 93\% of the larvae died by day 30. However, some adverse features of using neem have been observed. Neem powder produces bitterness in taste, which was removed by boiling, and neem oil was observed by Mathan *et al* (1992) to have nauseating, objectionable odour that was picked up by both the packaging and the fish.

The antifeedant and growth inhibitory effects of toosendanin, a limnoid allelochemical from the bark of the trees *Melia toosendan* and *M. azedarach* on variegated cutworm, *Peridroma saucia* were studied using different bioassays by Chen *et al.*, (1995). It was demonstrated that toosendanin significantly deterred feeding of 2\(^{nd}\) and 4\(^{th}\) instar larvae in diet choice and leaf disc bioassays, respectively. They were also able to prove that toosendanin was a reasonably effective antifeedant against *P. saucia* with a DC50 of 8.\(\mu\)g /cm\(^2\) in the leaf disc choice test.

Evaluation of the efficacy of refined soyabean and crude castor oils for the control of infestations of *Callosobruchus maculatus* and *C. phascoli* in stored chick-pea, *Cicer arietinum* (Pacheco *et al.*, 1995) proved castor oil as an effective protectant than soybean oil. No harmful effect was observed on the germination of oil treated seeds.

The potential of four vegetable oils and ten botanical powders in managing the bruchid beetles of legumes, *Callosobruchus chinensis, C. maculatus, C. rhodesianus* were looked in to by Rajapakse and Van Emden (1997) and all four oils tested (corn, ground nut, sunflower and sesame) significantly reduced the oviposition of all three bruchid species at 10ml/kg and also significantly reduced the longevity of adults of *C. maculatus* and *C. chinensis* at this dose. Only corn and sunflower oil caused a significant reduction of longevity of *C. rhodensianus* at 10ml /kg.
Laboratory investigations on the activity of neem leaf and seed extract in water or methylated spirit on *C. maculatus*, *Sitophilus oryzae* and *Cylas puncticollis* (Makanjuola, 1989) showed that the effectiveness of neem is affected by differences in insect behaviour. The extracts were more active as suppressants of *C. maculatus* than *Sitophilus* spp. there was no effect on *C. puncticollis*. All of the extracts tested resulted in a significant reduction in oviposition, percentage egg hatch and percentage adult emergence in *C. maculatus* and in adult emergence of *Sitophilus* spp.

Two commercially available repellents (oil of clove and citronellol) were found to be effective (Plarre et al., 1997) against the webbing clothes moth, *Tineola bisselliella* (Lepidoptera: Tineidae).

Inhibition of larval growth was directly related to concentration of the respective extracts (Villani and Gould, 1985). Out of 78 plant species (24 families) screened for antifeedant activity against the corn wireworm, *Melanotus communis*, five extracts from four families significantly reduced wireworm-feeding damage in a series of choice feeding tests. Two extracts, *Asclepias tuberosa* and *Hedera helix*, exhibited exceptional levels of feeding deterreny. Inspection on the effects of salt treatment of fish on the developmental biology of *D. maculatus* and *Necrobia rufipes* indicated prolonged larval development in both beetles in salted fish and larval mortality was total in *D. maculatus* at salt concentrations of 9.20% and 10.20%. (Osuji, 1975b).

Topical application of different doses of acetone extracts of *Anthocephalus cadamba*, *Lantana camara*, *Tectona grandis*, *Calophyllum* sp. and *Phyllanthus emblica* to the newly moulted last nymphal instar of *Dysdecus cingulatus* resulted in the 6th instars retaining varying degrees of nymphal characters. (Prabhu and John, 1975).
All the four plants viz. *Piper gunieense, Cyperus rotundus, Dennettia tripetala* and *Capsicum frutescens* were found to be effective in controlling *Dermestes maculatus* on stored, smoked catfish (*Clarias gariepinus* (Adedire et al., 1999).

Piper fruit oil at dosages of 0.125ml/25g fish and 0.150ml/25g fish were found to be efficient in the control of the development of *D. maculatus* adults and larval stages on tested dried fish (*Clarias* spp.) and was therefore recommended as appropriate dosages for prevention of insect infestation on dried fish (Amusan and Okorie, 2002).

Studies on the mode of action of citrus peel oils (Don-Pedro, 1999) revealed that they are fast-acting fumigant insecticides with possible neurotoxic or anti-respiratory properties. The rapid action of citrus oil fumes was demonstrated by LT50 values of 40.7, 106 h for lime peel oil and 4.6, 14.8 h for d-limonene against *C. maculatus* and *D. maculatus*, respectively.

*D. tripetala* seed powder showed higher repellency than pyrethrins. Acetone and ethanol extracts were good repellents to *D. maculatus*. Water extracts did not meet the minimum requirement for good repellents (Egwunyenga *et al.*, 1998).

The biological action of citrus peel oils was shown to depend on a strong fumigant action (Don-Pedro, 1996 a). Bioassays conducted showed that all the 6 citrus oils tested had vapour toxicity to adults of *C. maculatus*, *Sitophilus zeamais*, and *D. maculatus*. The 24-h LC50 value of lime peel oil (a typical citrus oil) vapour against *C. maculatus* was 7.99 μl/litre which made it 1.5 and 1.6 times less toxic to the smaller *S. zeamais* and the larger *D. maculatus* adults, respectively. When immature stages were fumigated, lime peel oil vapour had 24-h LC50s of 7.8 and 21.5 μl/litre against eggs of *C. maculatus* and *D. maculatus*, respectively and 9.1, 17.8, 23.1, 23.9 μl/litre/litre
against early larvae and pupae of *C. maculatus* and late larvae and pupae of *D. maculatus*, respectively.

Treatment (> 10 ml/mg) against *C. maculatus* or *Sitophilus zeamais*; (>20 ml/kg against *D. maculatus*) with citrus peel oils (lime, tangerine [mandarin] and grapefruit) reduced oviposition or larval emergence through parental adult mortality, but had no residual activity on the eggs or larvae produced by survivors (Don-Pedro, 1996 b). Oil-treated cowpeas (7 ml/kg against *C. maculatus*) or dried fish (28 ml/kg against *D. maculatus*), which caused 100% mortality 1 h after application lost all activity within 24 h, thus confirming the non-residual nature of the effects.

Don Pedro (1985) investigated the effectiveness of powders of the dried peel of orange (*Citrus sinensis*) and grapefruit (*C. paradisi*) using chips of dried cat fish (*Clarias* sp.) and found that orange peel had greater insecticidal and repellency effects than grapefruit peel. Treatment of fish with 14.1% by weight of orange peel poder killed 50% of adult *D. maculatus* after 7 days: a 21.3% treatment killed 99% in the same period. At applications of 15.0 and 18.0% by weight orange peel powder reduced progeny development and slowed larval development. At 18% the number of emerging larvae was reduced by 60% compared with the untreated control. Of the larvae that did emerge only 32.7% and 37.1% of the 18.0% and 15.0% treatments, respectively, developed into F1 adults compared with 87.8% of the larvae from the untreated controls. Subsequent work by Don Pedro (1996a; 1996b) demonstrated that topical toxicity of citrus peel oils was relatively ineffective when compared with activity in the vapour phase. The volatile components possessed activity against *D. maculatus* life stages, eggs being most susceptible and last instar larvae and pupae being least susceptible, though the differences were slight. In the presence of dried fish pieces the activity was greatly reduced as a result of sorption of the volatile components.
Population suppression and toxicity tests were carried out on dried fish pests using the African locust bean plant, *Parkia clappertoniana* (Odeyemi *et al*., 2000). The pod and pulp of *P. clappertoniana* at the rate of 1 g, 1.5 g, and 2.0 g for dry powder treatment per 100 g dried fish samples, were toxic to adults and larvae of *D. maculatus* and *N. rufipes*. The population of adults decreased significantly (P<0.05) on treated samples. The powder-in-oil treatment had more insecticidal effect on the beetles than the pulp.

Saha and Shajahan (1998) tested the effect of alcoholic extracts of neem and gamma radiation on the 6\(^{th}\) instar larvae of *D. maculatus* to investigate their effect on larval mortality, pupation, adult emergence and longevity. 80% larval mortality was obtained at a dose of 19700 ppm of the crude neem extract. Though this dose could not prevent adult emergence, it resulted in deformed adults with reduced life span.

Gakuru and Faua-Bi (1996) compared the effects of essential oils of four plants against *C. maculatus* and rice weevil, *S. oryzae*. Results proved that essential oils had no effect on *S. oryzae*, however, the essential oils of *Eucalyptus citriodora* and *O. basilicum* were more potent against *C. maculatus*.

The study of Lale and Ajay (2000) revealed that clove oil was significantly more toxic to adults and larvae of *Tribolium castaneum* than other oils tested. The period of exposure appeared to be the most important factor to determine the efficiency of extracts rather than dosage (El- Nahal *et al*., 1989).

Ali *et al*., (1983) reported that seeds treated with neem, coconut, mahua, sesame, and palm oil did not permit adult beetles (*C. maculatus*) to lay eggs and thus inhibited the development of subsequent population. Seed oils of *Cassia occidentalis* induced high mortality of bruchid eggs and first
instar larvae than the fresh and dry leaves or ground seeds (Lienard et al., 1993). Several fatty acids (linoleic, oleic, and stearic) present in the oil were responsible for this toxicity. Gupta et al., (2000) evaluated the efficacy of different vegetable oils such as castor, mustard, linseed, soybean, coconut, groundnut, and sesame against *S. oryzae*. It was observed that all the oils afforded protection over a period of around 120 days. Among these, mustard and linseed oils were significantly superior in comparison to other oils. According to Shaaya et al., (1997), edible oils are potential control agents against stored grain pests like *C. maculatus*, *S. zeamais*, *S. oryzae* and *S. cerealella* on the farm level itself.

Richa et al., (1995) have evaluated the effectiveness of essential oils of some plants (basil, geranium, rue, lemon grass, citronella, eucalyptus, and lemon) in protecting faba beans from *C. chinensis*. According to their findings, essential oils of basil and geranium had the greatest insecticidal effect, while oils of lemon grass and eucalyptus were not toxic to adults but showed some effect on oviposition. Insecticidal effect of volatile oils of *Lippia adoensis*, *Cymbopogon citrates*, *Lantana camara* and *Chromolaena odorata* against *C. maculatus* was studied by Gbolade and Adebaye (1995).

Plant oils obtained from cottonseeds, soybean, maize and peanuts act as very good repellents against *S. granaries* in stored wheat (Yun and Burkholder, 1981). Jilani and Su (1983) have demonstrated the repellent effects of turmeric (*Curcuma longa*), neem (*A. indica*) and fenugreek (*Trigonella foenumgracum*) against three species of stored product insects viz. *T. castaneum*, *R. dominica* and *S. granaries*. Results showed that the turmeric powder was the most effective against *S. granaries* and *R. dominica* while only solvent extract was effective against *T. castaneum*. Repellent and growth-inhibitory effect of turmeric oil, sweetflag oil, neem oil, and Margosan-O on red flour beetle, *T. castaneum* were reported by Jilani et al., (1988). Their
report indicated that repellency increased with increasing concentration of the oils and Margosan.

Singh and Singh (1991) screened 31 essential oils of plant origin for repellent and insecticidal properties against house fly, *Musca domestica*. The essential oils obtained from *Ocimum gratissimum, Thymus serpyllum, Illicium verum, Myristica fragrans,* and *Curcuma amada* showed 100% repellent activity, and *A.calamus* showed 40% activity.

Malik and Naqvi (1984) have screened seven plant species for their repellent activity against *T. castaneum* and antifeedant activity against *R. dominica*. The best repellent activity was for the rhizomes of *Saussurea lappa* and antifeedant activity for the leaves of *Chenopodium ambrosioides* and for azadirachtin isolated from neem kernal.

Behal  (1998) has screened 12 plant oils for their repellent effect against the rice moth, *C. cephalonica*. Study showed that there was a complete repellency for larvae with sweetflag, (*A. calamus*) oil irrespective of its concentration, while with other oils, a concentration dependent repellency was noticed. Petroleum ether extracts of *Cassia tora, C. fistula,* and *C. articulata* seeds exhibited more than 80% repellency against *T. castaneum* (Pradeep and Radhakrishnan, 1999).

Sahayraj and Paulraj (2000) observed that *Spodoptera litura* larva was repelled by groundnut leaves treated with *Tridax procumbens* leaf extract and the repellency increased as the concentration of leaf extract increased.

The percent repellency was found to decrease over a long interval of time   (Urs and Srilatha, 1990). When essential oil of eucalyptus was used against the rice weevil, *S. oryzae*, 80% repellency was shown after 10 min, 50% after 30 min and after 60 min it decreased to 20% (Ahmed and Eapen,
Malik and Naqvi (1984) also reported a similar time-dependent decrease of repellent property in the case of *T. castaneum*.

Dormusoglu *et al.*, (2003) studied the effects of Neem Azal T/S and neem oil on different stages of *Nezara viridula* (L.) (Heteroptera: Pentatomidae) and observed that both products had no significant effect on adults and newly laid eggs. However neem oil was found to be more effective than Neem Azal T/S on nymphs and old laid eggs after 7 and 14 days respectively.

Zabel *et al.*, (2002) investigated the effect of neem extract on *Lymantria dispar* and *Leptinotarsa decemlineata* and proved high antifeedency and low toxicity of the plant preparation on *L. dispar* and on 3rd instar larvae of *L. decemlineata*.

Ahmad *et al.*, (2003) conducted experiments on the effects of neem-treated aphids as food/host on their predators and of the three neem preparations sprayed upon eggs. Only neem oil was found to exert a negative impact on the hatching rate of *Cocinella septempunctata* and *Chrysoperla carnea* and the 1st instar larvae *Episyrphus balteatus* proved to be highly susceptible, when feeding 24h. on aphid sprayed with neem kernal water extract.

Ma *et al.*, (2000b) studied the biological effects of azadirachtin on *Helicoverpa armigera* fed on cotton and artificial diet and observed high mortality of larvae fed on potted cotton plants (*Gossypium hirtum* L) sprayed with formulated neem extract (3% azadirachtin emulsifiable concentrate). He also found physiological effects such as difficulty in moulting between various instars and abnormal pupae in larvae fed on the artificial diet.

Bruce *et al.*, (2004) studied effects of neem oil on oviposition, development, and reproductive potentials of *Sesamia calamistis* and *Eldana*
saccharina Walker and observed low oviposition rates, immature survival, fecundity, and egg viability in the neem treatments and a relatively high persistence of neem oil.

Mathen et al. (1992) investigated the insecticidal properties of cashew nut shell liquid and oils of coconut, neem, palm, gingelly, mustard, sunflower, safflower, castor seed, rice bran, ground nut, and hydnocarpus, using dried silver belly (*Leiognathus* sp.). Oils were sprayed on to the packing material, the gunny bags, and on the fish themselves. The authors stated that mustard oil was observed to be the best insect repellent, the treated sample remaining insect free for 40 days, followed by hydnocarpus, sunflower and cashew. Unfortunately, little data was given, particularly regarding application rates and the species of insect used in the experiment.

Peppers (*Capsicum* sp.) are used traditionally in Africa as a means of repelling blowflies but there is no evidence to suggest a use on dried fish. Pepper is used domestically as a preservative for prawns in Kerala, India. When cured prawns were sprinkled with 1.5% by weight of pepper powder and stored in a mite-infested godown (store) they remained insect free for as long as the pepper smell persisted, about 7 weeks. (Pillai, 1957).

Wood et al., (1987) studied the effect of salt on the susceptibility of dried whiting to attack by dermestid beetles. The maximum weight losses in unsalted fish varied between trials and ranged from 15 to 41%. Increases in salt content above the natural 2% level to 5% did not give any marked protection against insect infestation. A salt content of greater than 9% largely protected the fish from damage, reduced weight losses to less than 10% and greatly inhibited insect development.

Experiments with salted dried fish (the freshwater fish, *Roccus chrysops* being used) showed that a salt content of 13% or more prevented the
development of infestation by *D. maculatus* from eggs. The adverse effects were reduction of larval survival and retardation of larval development rather than reduction of egg viability. The results suggested that eggs laid in the crevices of salted fish will hatch but that the larvae will mostly perish (Mushi and Chiang, 1974).