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The effect of *Eucalyptus camaldulensis* powder (Dehnh) against the larvae of khaprabeetle *Trogdermagranarium* (Coleoptera :Dermestidae)

دراسة تأثير بدرة أوراق نبات الكافور على يرقات خنفساء الخابرا .

A thesis submitted in partial fulfillment of the requirements for the degree of B.Sc. Agric.in plant Protection.

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الآية

قال تعالى

قَالَ تَزْرَعُونَ سَبْعَ سِنِينَ دَأْبًا فَمَا حَصَدْتُمْ فَذَرُوهُ فِي سُنْبُلِهِ إِلَّا قَلِيلًا مِمَّا تَأْكُلُونَ
(47) ثُمَّ يَأْتِي مِنْ بَعْدِ ذَلِكَ سَبْعٌ شِدَادٌ يَأْكُلْنَ مَا قَدَّمْتُمْ لَهُنَّ إِلَّا قَلِيلًا مِمَّا
تُحْصِنُونَ (48) ثُمَّ يَأْتِي مِنْ بَعْدِ ذَلِكَ عَامٌ فِيهِ يُغَاثُ النَّاسُ وَفِيهِ يَعْصِرُونَ (49)

صدق الله العظيم

سورة يوسف الآيات من 47- 49

DEDICATION

I would like to dedicate my effort to
My parents, Brothers, lovely sisters,
And to My friends

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ABSTRACT

The experiment was carried out in the Entomology laboratory in Sudan University of Sciences and Technology Faculty of Agricultural Study Department of plant protection. summer season 2016 to evaluate the effects of cafour powder (*Eucalyptus camaldulensis* (Dehnh)) on the khapra beetle (*Trogoderma granarium*) mortality rate on dura, with three concentration 2g, 4g, 6g.

The results showed there is no mortality in the first 24hours. While there is a mortality of 26.67% after 72 hours with concentration 6g. The highest mortality was 13.33after week using 2gm.

Adding to that it has repellent effect and from general evaluation it became clear that cafour powder does not have an effective mortality on khapra larvae.

ملخص البحث

اجريت التجربة في معمل الحشرات بجامعة السودان للعلوم والتكنولوجيا كلية الدراسات الزراعية قسم وقاية النبات في موسم (2016) لدراسة اثر اضافة بودرة الكافور علي كفاءة تغذية يرقات حشرة الخابرا علي الذره بالإضافة الي أثره القاتل باستخدام ثلاثه تركيزات 2 جم، 4 جم، 6 جم.

اظهرت النتائج انه لا توجد نسبة موت خلال ال 24 ساعه الأولى بينما كانت نسبة الموت خلال ال 72 ساعه بمعد 76 . 26 % عند التركيز 6 جم بعد مرور اسبوع كان اعلي نسبة موت 13.33 % سجلت عند التركيز 2 جم.

بالإضافة الي ذلك فالكافور اثر طارد ومن التقييم العام للتجربة اتضح ان بودرة الكافور ليس له اثر فعال في قتل يرقات الخابرا.

CHAPTER ONE

INTRODUCTION

Sorghum is a major crop of the world with various uses. The estimated world area of sorghum in 1972 was 40 Mya, the largest areas being in India (16 Mya) and Africa (10.3 Mya). By 1980, sorghum production had spread throughout most parts of the world (Hume & Kabete, 1981). Sorghum grain is used for stock feed in the New World, Japan and Europe. It provides human food and beer in India and Africa.

Sweet sorghum has sweet juicy stems which may be used for forage and silage or to produce syrup. The juicy stems are often chewed as a snack by humans in southern Africa. In China sugar is produced from sweet sorghum (Doggett, 1988). Brazil currently relies on sugarcane for the production of ethanol but cassava and sweet sorghum are also used. The increase in human population led automatically to increase in the demand for food production. This necessitates more efforts to be devoted for mitigating the expected negative impacts of plant pests on food crops.

However, at the present time pesticides were considered indispensable for sustainable agriculture production, in addition to their role in the protection of human health especially in the tropics. But, the increasing and irrational use of synthetic pesticides has become a source of great concern because of their possible effect on human health and non-target components of the environment. This concern is heightened by the non-specificity and high toxicity of some pesticides and development of resistant strains of microorganisms against other ones. The foregoing has initiated the exploration of safe alternate antimicrobial agents (Saeed, 2008).

Khapra beetle, *Trogoderma granarium*, is a serious pest of stored grain products in Africa, the Middle East, the Near East, and pockets of Europe and eastern Asia (USDA 1983, CABI/EPPO 1997, CAB 2004, EPPO 2005).

It has been nominated as one of the 100 worst invasive species worldwide (Lowe *et al.*, 2000). This insect is not known to occur in the United States, but the potential introduction of this insect into the US has been a serious concern for a number of years. In 1998, USDA sponsored a comprehensive pest risk assessment for *T. granarium* (Pasek 1998). The assessment evaluated the likelihood that the beetle might become established in the US and the economic and environmental consequences if it would establish.

(Pasek,1998) considered both the likelihood and consequences of establishment to be high; however, economic and environmental impacts were predicted to be moderate and high, respectively. We utilize the original document as the foundation for our mini-pest risk assessment.

The purpose of the mini-risk assessment is to further evaluate several factors that contribute to pest risk and where appropriate to re-evaluate risk ratings based on current research. This information can then be applied to the refinement of survey and detection programs.

The benefits for the treatment or prevention of disease or infection that may accrue from either dietary or topical administration of Maringa preparations (e.g. extracts, decoctions, poultices, creams, oils, emollients, salves, powders, porridges) are not quite so well known (Palade., 1996). Although the oral history here is also voluminous, it has been subject to much less intense scientific scrutiny, and it is useful to review the claims that have been made and to assess the quality of evidence available for the more well-documented claims. The readers of this review are encouraged to examine two recent papers that do an excellent job of contrasting the dilemma of balancing evidence from complementary and alternative medicine (e.g. traditional medicine, tribal lore, oral histories and anecdotes) with the burden of proof required in order to make sound scientific judgments on the efficacy of these traditional cures (Talalay *et al.*, 2001). Clearly much more research is justified, but just as clearly this will be a very fruitful field of endeavour for both basic and applied researchers over the next decade.

This study was designed to test the effect of different concentration of *Eucalyptus camaldulensis* against larvae of khapra beetle.

CHAPTER TWO

LITERATURE REVIEW

2.1.Khapra Beetle

2.1.1. Classification:

Kingdom: Animalia

Phylum: Arthropoda

Class: Insecta

Order: Coleoptera

Family: Dermestidae

Scientific name: *Trogodermagranarium*Everts, 1898

Synonyms: *Trogodermakhapra*Arrow, 1917

*Trogodermakoningsbergeri*Pic, 1933

*Trogodermaafrum*Priesner, 1951

*Trogodermagranarium*ssp. *afrum*Attia and Kamel, 1965

Common names: khapra beetle (English)

2.1.2. Host range:

Unlike most Dermestidae (Schultz& Holm, 1985) this species feeds by preference on grain and cereal products (particularly wheat, barley, oats, rye, maize, rice, flour, malt, and noodles) and can be a serious pest of such commodities in store. The damage is done in the larval stage as the adults do not normally feed (Freeman, 1980). Khapra beetle will attack almost any kind of material (Cotton, 1956) such as dried blood, dried milk, fish meal, wool, goat skins and many more (Dillon, 1968). They can feed on products with as little as 2% moisture content and can develop on animal matter such as dead mice, dried blood, and dried insects.

Pasek (1998) and CPC (2005) list the primary seed and cereal grain hosts. These are (alphabetical order on scientific name): *Avenasativa*(oat), *Cicerarietinum*(garbanzo), *Glycine max* (soybean), *Hordeumvulgare*(barley), *Lens culinaris*(lentil), *Oryzasativa*(rice), *Pisumsativum*(garden pea), *Sorghum bicolor*(grain sorghums), *Triticumaestivum*(wheat), *Vignaunguiculata*(cowpea), and *Zea mays* subsp. *mays* (corn). Preferred animal feeds and concentrates include: rolled and ground barley, ground corn, ground dog food, rolled oats, dried orange pulp, ground rice, and cracked and ground wheat bran. Nuts that may serve as primary hosts include: *Arachishypogaea*(peanut), *Caryaillinoensis*(pecan), *Juglans* spp. (walnut), and *Prunusdulcis*(almond). Grocery commodities that sometimes serve as hosts include: bread, dried coconuts, cornmeal, crackers, white and whole wheat flour, hominy grits, baby cereals, pearl barley, and wheat germ. Larvae can feed, but not fully develop on seeds of *Medicagosativa* subsp.

sativa(alfalfa), noodles, *Phaseoluslunatus*(lima bean), and raisins.

2.1.3.A Description of the different life stages follow:

2.1.3.1. Eggs:

Initially milky-white, later pale-yellowish; typically, cylindrical, 0.7 mm long and 0.25 mm broad; one end rounded, the other more pointed and bearing a number of spine-like projections, broader at the base and tapering distally (OEPP/EPPO, 1981). Laid loosely and singly in the host material (APHIS, 1984).

2.1.3.2. Larva:

Total length of the first-instar larva is 1.6-1.8 mm, a little more than half of which consists of a long tail, made up of a number of hairs borne on the last abdominal segment. Body width is 0.25 -0.3 mm, and colour uniformly yellowish-white, except for the head and body hairs which are brown. The head bears a short antenna of three segments. A characteristic feature of the larva is the presence of two kinds of body hairs: simple hairs, in which the shaft bears many small, stiff, upwardly directed processes; and barbed hairs, in which the shaft is constricted at regular intervals, and in which the apex consists of a barbed head. This brown or yellowish-brown head is as long as the combined lengths of four of the preceding segments. Simple hairs are scattered over the dorsal surface of the head and body segments. The tail consists of two groups of long simple hairs, borne on the 9th abdominal segment. Barbed hairs are

found in pairs of tufts, borne on certain abdominal tergites. As the larva increases in size, the colour changes progressively from the pale yellowish-white of the first-instar larva to a golden or reddish-brown. The density of the body hairs increases but these hairs and the tail become much shorter in proportion to the length and breadth of the larval body, and in the 4th instar the hairs give the appearance of four dark transverse bands. The mature larva is approximately 6 mm in length and 1.5 mm in breadth (OEPP/EPPO, 1981).

Morphologically, the mature larva of Khapra beetle can be separated from that of *T. versicolor* by the absence of a dark pretergal line on the 7th and 8th abdominal segments, such a line being faint or absent on the 7th segment and never present on the 8th segment in Khapra beetle (OEPP/EPPO, 1981), Three pairs of legs (APHIS, 1984).

2.1.3.3. Pupa:

At the last ecdysis, the larval skin splits, but the pupa remains within this skin for the whole of its life. The pupa is of the exarate type; male smaller than female, average lengths being 3.5 mm and 5 mm, respectively. (OEPP/EPPO, 1981). Whitish colour (APHIS, 1984).

2.1.3.4. Adult:

Oblong-oval beetle; about 1.6-3.0 mm long by 0.9-1.7 mm wide; males brown to black, with indistinct reddish-brown markings on the wing covers; females are slightly larger than males, and lighter in colour; antennae are 11-segmented; head is small and usually deflexed.

Several other species also occur in grain and other stored products, sometimes in large numbers, and they may be confused with Khapra beetle. It is important that any field identification should be checked in the laboratory. For more information, see Hinton (1945), Beal (1956; 1960), Faber (1971).

Khapra and Warehouse beetles are similar in many ways, and they can only be distinguished by dissection of the genitalia or by DNA methods. For obvious reasons the presence of Warehouse beetle in Australia increases the risk of Khapra beetle establishing here.

The most likely stage to be seen during inspection is the hairy larva and the most usual evidence is cast larval skins. Special attention should be given to any produce from the areas where the pest is indigenous, especially oilseeds and oilseed products, pulses, cereals and gums, as well as used and new sacks and

hessian from these areas. Examine malt from temperate areas carefully. In warehouses which are suspect, examine cracks and crevices and look behind any panelling against walls. In ships, look also under rust scale, under timber coverings of tanks, on ledges, etc. In dry cargo containers, look between floor boards and behind linings. Larvae are most likely to be seen during the hour before dusk since they tend to be more active at such periods (OEPP/EPPO,1981).

2.1.4.Life history:

The adults are short-lived, mated females living 4-7 days, unmated females 20-30 days and males 7-12 days. They do not fly and feed very little, if at all. Mating occurs about 5 days after emergence. The beetle can lay a full complement of eggs following a single mating, but a second mating greatly increases the total number of eggs produced: once-mated females lays about 60 eggs, whereas twice- mated individuals laid about 60 and then 500 eggs after the respective matings. Delay i n mating of 15-20 days' results in up to 25% reduction in fecundity. The preoviposition period, which is not affected by humidity, is negligible at 40°C, 1 day at 35°C, 2 days at 30°C, 2-3 days at 25°C, and, at 20°C, no eggs are produced. Under optimum conditions, the female lays an average of about 50-90 eggs loosely in the host material. The eggs hatch in 3-14 days (OEPP/EPPO,1981). Optimum conditions for development are 33-37°C, 45-75% r.h. (Howe, 1958).Khapra beetle is able to survive short periods at 60°C, and at -15°C for several hours. The upper limits are considered to be in the vicinity of 46°C. At 70% r.h., minimum temperature of development is about 22°C

On hatching the larvae are about 1mm long. There are five molts in the development of the larvae, and the cast skin is shed following each molt (Morschel, 1972). Both short- and long-lifecycle larvae can develop. Larvae may enter diapause under certain conditions, which then make it difficult to control them chemically. OEPP/EPPO (1981) mentions that if the temperature falls below 25°C for any period of time, and, sometimes, if the larvae are very crowded, they may enter diapause and development ceases. The larvae are cold-hardy, surviving temperatures below -8°C. Diapause often occurs at constant temperature, below 30°C. In diapause, the larva can moult but is relatively inactive and rarely feeds. It tends to seek out crevices in the fabric of buildings. A larva can remain in this state for several years, but the provision of a new consignment of food, especially in warm conditions, may stimulate renewed development and pupation. Young larvae are unable to feed on whole grains

and depend on damaged grains or grain products for food (they readily attack softer foods such as nuts). Such damaged grains are always present in practice in lots of stored grain. Older larvae can feed on whole grains.

The amount and condition of the food present affects the speed of development, but larvae can survive long periods (at least 13 months) without food. These starving larvae pupate within a week on the return of favourable conditions such as high temperature and availability of food. Starvation of dormant larvae for 3 months, followed by a brief period of feeding, results in the production of 40% of the normal number of eggs. However, this percentage is ample for the survival

of the pest. One to 3 months of starvation does not affect the pupation rate of dormant larvae. For more information, see Hinton (1945), Howe (1952), Hadaway (1956), Burges (1959; 1963), Faber (1971), Karnavar (1972), Nair & Desai (1972). Complete development takes place within the range 21 to over 40°C. The life cycle from egg to adult

Takes an average of 220 days at 21°C, 39-45 days at 30°C and 75% RH and 26 days at 35°C, the optimum Development can take place at a relative humidity as low as 2%, at which the life cycle is prolonged. OEPP/EPPO (1981). The rate of increase of populations at 33-37°C is about 12.5 times per month: this compares with 20 times at 32-35°C (minimum RH 30%) for *Rhyzoperthadominica* and 25 times at 27-31°C (minimum RH 50%) for *Sitophilusoryzae*, the principal competitors of Khapra beetle as pests of whole grain. In the zone where Khapra beetle is indigenous, where mean temperatures are consistently above 25°C, the larvae develop rapidly into the pupal stage, e.g. in 15 days at 35°C (OEPP/EPPO, 1981).

2.1.5.Distribution:

It is very important to distinguish between records which relate to introductions and those of established infestations. Khapra beetle is established within an area broadly limited north by the 35° parallel, south by the Equator, west by West Africa and east by Myanmar; i.e. the warm dry regions along the Suez route from the Indian subcontinent to Europe. Khapra beetle has been introduced into areas of similar climatic conditions elsewhere, especially the alternative route between India and Europe around Africa. Initially, these introductions caused severe damage but outbreaks have been local and have, in most cases, been eradicated. In general, Khapra beetle is only successful in competition with other major stored product pests in conditions of low

humidity. It has also established in some areas of unfavourable climate, in protected environments only, for example in Western Europe and Japan. (OEPP/EPPO,1981).

Khapra beetle is a native of the Oriental region, but has become established in a number of Asian, Middle East and African countries, as well as some European countries. In the USA a Khapra beetle infestation in 1954 resulted in a successful eradication program (Dillon, 1968). The USDA now regulates the importation of certain items from 25 countries.

2.1.6. Estimate of Economic impact on production, allied industries and native ecosystems:

2.1.6.1. General:

The khapra beetle is principally a serious pest of stored products under hot dry conditions; complete destruction of grain and pulses may take place in a short time. In humid climates, the rates of increase of its competitors are so much greater that it has difficulty in establishing itself. However, in such areas, it lives at the inner edge of the expanding hot zone of stacks or bulks, in which heating has been induced by the activity of other species. In the EPPO region in the 1970s, Khapra beetle was rated as of considerable economic importance in Cyprus, Tunisia and Turkey. Khapra beetle, depending upon existing conditions, may cause losses to stored grain of 5 to 30 percent and losses have been known to reach as high as 74 percent. The most favourable conditions for multiplication and damage is in bulk grain under extended storage. Despite this, it is likely that direct losses to stored grains in Australia by susceptible Khapra beetle strains would be limited. This is because current phosphine treatments used to control endemic grain pests would also control non-resistant Khapra beetle populations.

2.1.6.2. Estimate impact on trade:

International grain markets are becoming more discerning and for the Australian industry to continue to be successful, it is essential that we adapt to these changing markets especially given that 75% of our annual harvest is exported. Customers continue to demand grain that is completely free of grain insects. Especially in the case of Khapra beetle it would be of the utmost importance for Australia to be able to claim freedom of this pest.

When Australia was erroneously listed as “Khaprabeele” country in the late 1940’s, it took over 15 years of lobbying and publication to have this stigma

removed (Emery, 1999). Many Australian export markets could disappear immediately if Khapra beetle is found to be present (Butcher & Dean, 1995). Under 4 scenarios in an assessment of the potential economic impact of Khapra beetle in Western Australia, costs associated with export market losses ranged from \$46 million/year to 117

million/year, while the present value of costs over a 30 year period ranged from \$200 million to \$1.6 billion (McElwee, 2000). These costs did not include the possibility that adequately treated grain might be accepted by Khapra beetle-free export destinations. It is possible (although considered unlikely by many grain pest experts) that Khapra beetle could be controlled to acceptable levels by existing (phosphine) or additional (methyl bromide, heat, controlled atmospheres, irradiation) control measures. In this case the costs of Khapra beetle to Western Australia would be substantially less than the estimates quoted above. Conversely, it is possible that even countries listed as Khapra beetle countries may decline Western Australian wheat because they do not want a particular strain of the beetle or because of market or political pressures.

2.1.6.3. Environmental Impact:

Apart from the destruction of grain products by Khapra beetle, ingesting products contaminated with body parts, setae and cast larval skins can result in gastro-intestinal irritation. Asthmatics and sensitised individuals are also at risk, as contaminants are highly allergenic.

Since infestations would most likely be confined to grain storage facilities and other buildings, this pest is not expected to have significant impacts on natural environments or endangered / threatened species (Pasek, 1998).

The use of methyl-bromide or other fumigants to eradicate or control Khapra beetle will likely produce adverse effects to the environment and human health. Methyl bromide is an ozone-depleting substance, and human exposure to high concentrations can result in the failure of the central nervous and respiratory systems (Pasek, 1998).

2.1.6.4. Guidelines for the selection of chemical control treatments:

Worldwide, the fumigant of choice for quarantine treatment against Khapra beetle is methyl bromide. This is despite its known high level of tolerance to the fumigant, particularly when in diapause. Recommended dosage rates against the

pest tend to be twice as high or more than against typical stored product pests (eg. Bond 1984) Practical problems with fumigating some oily, high risk commodities (eg. expeller cake) with methyl bromide further compounds the difficulties.

In the survey by Rees & Banks (1999) the following insecticidal treatments are considered particularly:

- ☐ Fumigation - (methyl bromide and phosphine)
- ☐ Controlled atmospheres
- ☐ Heat
- ☐ Irradiation

Despite the importance of Khapra beetle to a number of quarantine authorities there is remarkably little modern (post 1960) literature on the response of the pest to insecticidal measures. This is particularly so for the response of diapause larvae - assumed here to be the main form of the pest requiring quarantine control. Many of the available scientific studies do not take adequate precautions to ensure the at least part of their test samples is well established in diapause. There is a risk that these studies will give rise to dosage schedules that will not eliminate diapause larvae, though they may well control the more susceptible active larvae and other developmental stages.

The Australian Department of Health, a predecessor of AQIS, commissioned studies in the UK to remedy the lack of reliable data on diapause larvae. Extracts (Rees & Banks, 1999) from these studies (Spratt *et al.* 1985, Bell *et al.* 1983, 1985) are included below.

2.1.6.5. Methyl bromide:

Historically, dosage recommendations for control of Khapra beetle have been based on „double the normal dosage“ for typical stored product pest control. The latter are often aimed at $ct = 200 \text{ g h m}^{-3}$ at 20°C , implying $ct = 400 \text{ g h m}^{-3}$ at 20°C for Khapra beetle. This is close to the value of 480 g h m^{-3} for 100% kill at 20°C given by Bell *et al.* (1985), but less than the Russian quarantine dosage implied by Mordkovitch and Sokolov (1992) of 600 g h m^{-3} . Bogs (1976) give a dosage of 600 g h m^{-3} for $>15^{\circ}\text{C}$, which may be the origin of this recommendation.

During the apparently successful Khapra beetle eradication campaign in the 1950s in USA, the dosage recommendations finally adopted correspond to a

minimum ct of about 1200 g h m⁻³ at unspecified temperatures (initial dosage 80 g m⁻³, 32 g m⁻³ remaining after 24 hours) (calculated from Armitage 1958).

Exposures exceeding ct = 400 g h m⁻³ are easily obtained at 20°C with dosages of 48 g m⁻³ for 24 hours with most commodities in well-sealed enclosures. Oily and finely divided commodities may need additional dosage or topping up to achieve target ct-products and as a result residual bromide

levels may exceed established tolerances (eg. 50 ppm in cereals, Australian MRL). There is also a risk of taint or quality change in some materials. Alternative treatments may be considered more appropriate despite long history of methyl bromide use in such situations.

2.1.6.6. Phosphine:

Phosphine fumigation is not currently approved by AQIS as a quarantine treatment against Khapra beetle. Reasons for this appear to be historical - with suitable precautions to prevent leakage and exposure times of 12 or more days, depending on conditions, data available for phosphine action on Khapra beetle, until recently, supported consideration of its use as an alternative to for this pest. However, as noted below, resistance development may now have rendered this former option inappropriate.

Khapra beetle, even as a larva in diapause, is quite sensitive to phosphine. Australian dosage rates for control of *Sitophilus* species are sufficient to control normally-susceptible Khapra beetle at >20°C, and appear to be so too for resistant Khapra beetle so far encountered. Data on the latter is insufficient to establish a firm recommendation.

The best studies on action of phosphine against Khapra beetle are those of Bell *et al.* (1983, 1985) and Hole *et al.* (1976). There are numerous other studies (e. g. Lindgren *et al.* 1960, El-Lakwah *et al.* 1989, Punj and Girish 1969, Dhaliwal and Rattan 1973), but as these are carried out under conditions where diapause is absent or not adequately proven, they are, at best, indicative only of the relative susceptibility of Khapra beetle to phosphine.

All data available to us shows that phosphine dosages recommended currently for control of stored product pests in stored grain, including *Sitophilus* species and resistant *Rhyzopertha dominica* (currently known strains, 1998) will be more than adequate to eliminate normally-susceptible Khapra beetle. This applies to the most tolerant stages of the pest known, ie. diapause larvae below 25° and egg stage above this.

Australian recommendations for phosphine use against phosphine-tolerant species of stored grain pest (Winks *et al.* 1980) specify commodity temperatures must exceed 15°C. The data of Bell *et al.* (1985) shows that phosphine could be used down to 10°C against Khapra beetle provided an adequate exposure time was allowed (16 days at 10°C).

2.1.6.7. Other fumigants and fumigant mixtures:

Data on the effectiveness of other fumigants and for fumigant mixtures is insufficient to base recommendations for quarantine treatment on. Almost all studies do not adequately show that larvae in diapause have been tested. An exception is Bell *et al.* (1985) who tested a methyl bromide / methyl chloroform mixture. However, methyl chloroform is no longer available, as it is an ozone - depletory.

2.1.6.8. Controlled atmospheres:

Carbon dioxide-based atmospheres (< 70% CO₂) are less effective against Khapra beetle than most other stored product pests, requiring much prolonged exposure for control of diapause larvae. Annis (1987) concluded that 16 days' exposure at 80% CO₂ (20-30°C) was required to eliminate Khapra beetle (data of Spratt *et al.* (1985), Verma and Wadhi (1978) and Le Torc'h (1983)).

Low-oxygen atmospheres however appear to be quite effective against Khapra beetle, including eggs and diapause larvae (Verma and Wadhi 1978), requiring the same exposures as other tolerant stored product insect pests. Annis (1987) suggests 0.1% oxygen at 20-29°C for more than 20 days.

High pressure CO₂ may be effective with only brief exposures (a few hours). No data is available to us on effectiveness of the new technique on Khapra beetle.

In summary, some CA treatments are effective against Khapra beetle at exposure periods only slightly longer than required for phosphine. While the difficulties and costs associated with CA application in large structures and containers may limit its use there, small-scale packaging in nitrogen or CO₂ in barrier film packs may be assumed to be fully insecticidal against Khapra beetle inadvertently

included, provided temperatures exceed 20°C (no data available below this), exposures exceed 20days and the atmospheres in the packs do not exceed 1% O₂.

2.1.6.9. Heat:

Heat treatment appears to be a potentially useful technique for quarantine treatment of heat tolerant commodities against Khapra beetle. There is a surprising quantity of data available to substantiate this. Much of it is antique, but of good quality. For instance, Husain (1923) studied heat disinfestation of wheat from Khapra larvae. As expected the resulting temperature/time relationship is of the form typical of heat/time curves shown by many stored product pests (Banks & Rees, 1999).

Overall the data shows that, unexpectedly, Khapra beetle is not the most heat tolerant common stored product pest. Some stages of *R. dominica* are more so (Husain 1923), and heat dosages aimed at complete kill of *R. dominica* can be expected also to eliminate Khapra beetle. This is despite the known unusual tolerance of Khapra beetle to moderately high temperatures, around 41°C, lethal to many species, and its unusually high optimum developmental temperature. Note, however there are some inconsistencies in the data between authors that give rise to some concern and additional studies are required for conclusive development of recommendations.

In summary, most of the available laboratory data show temperatures above 55°C are lethal to all stages of Khapra beetle in less than 15 minutes. However, response data for diapause larvae is very limited. The USDA recommendation of 7 minutes at 66°C seems unnecessarily stringent, but may actually include some allowances for time that heat takes to penetrate to the actual target pest through structures, commodities or residues.

It is suggested (Rees & Banks, 1999) that a conservative heat dosage of at least 120 minutes at 55°C at the site of the infestation would be adequate to eliminate Khapra beetle. Due allowance for time to heat the site to the required temperature would need to be added to any specification.

2.1.6.10. Irradiation:

Rees & Banks (1999) refer to many laboratory-based studies on use of irradiation to sterilise Khapra beetle for its control. Most of these studies are directed at adult insects, often not the stage of concern in quarantine treatments.

Studies on effectiveness of irradiation on apparently diapause larvae are not adequate to base a sound assessment on, but they suggest diapause larvae are very tolerant to irradiation at low temperatures (< 20°C). Data is available in Rahalkar and Nair (1968).

2.1.7. Resistance:

2.1.7.1. Resistance to phosphine:

While susceptible Khapra beetle, even as diapause larvae, appear to be controllable with standard dosage rate and exposures to phosphine, there is evidence that resistance to phosphine has already developed in this species. Prolonged exposures at substantial phosphine concentrations are required to control the tolerant strains so far identified. There has been no substantial recent survey of resistance levels to phosphine in Khapra beetle. However, judging from the resistance levels in some other species of stored product pest from the Indian subcontinent, resistance levels may be substantial and even to a level to jeopardise achievement of control to quarantine standards by normal high dosages for prolonged periods (eg. 1.0 g m⁻³ for 12 days at 20-30°C as given for *Sitophilus* control by Anon. (1993).

At present there are no data which suggests that any of the resistant strains found to date would not be controlled by „*Sitophilus*“ dosages for phosphine. However, the known presence of substantial resistance to phosphine together with the continued widespread poor use of phosphine in some Khapra countries suggests that phosphine is probably not now a fumigant of choice for quarantine use against Khapra beetle.

Introduction of a strain of Khapra beetle tolerant of phosphine into Australia would be a particularly challenging disaster, since phosphine would be one of the most important tools which typically would be used in an eradication or control attempt.

2.1.7.2. Resistance to methyl bromide:

Methyl bromide is not at present used repeatedly and rarely as a fumigant against established Khapra beetle populations. Consequently, presence of other than a natural variation of tolerance to methyl bromide in the field is unlikely. This contrasts with the known situation for phosphine.

Slightly increased levels of tolerance to methyl bromide can be selected for in the laboratory with levels of 2x resistance achieved after many selections (Mordkovich and Sokolov 1992). While this resistance level is low, it would jeopardise control with standard, already high dosages used currently with methyl bromide for quarantine purposes.

2.1.8. Biological control:

Infestations by dermestids are usually controlled by treatments with insecticides. However, insecticides may cause hazards to man and the environment. Especially in the storage of small subsistence farmers in the tropics the use of insecticides may be dangerous and their costs prohibitive. Hence, there is a need for the development of alternative methods such as biological control, an efficient component in integrated pest management. Al-Kirshiet *al.* (1997) considers the potential of the larval parasitoid *Laelius pedatus* (Say) to control the Khapra beetle in cereals. The parasitoid wasp has desirable characteristics to control Khapra beetle. However, the advantages of biological control for Khapra beetle in the high valued grain industries of Australia would be limited.

2.1.9. Technical information for planning surveys:

The entry potential of Khapra beetle is considered to be very high, since the larvae can survive for several years without food. They have a very wide host range, and since they may hide in such diverse items as hessian cloth, crude rubber, wool, vermiculite, timber and cotton waste, the chance of an undetected incursion substantially increases. Asia, the Middle East and African countries are high risk regions and considered to be endemic for Khapra beetle. Establishment potential is considered to be potentially high, since the climate, especially under bulk storage conditions, are suitable for Khapra beetle, and detection may go unnoticed in instances where the continuous identification in the presence of Warehouse beetle is not practised.

2.1.10. Trapping:

Trapping is used to monitor the presence of Khapra beetle in warehouses and other storage facilities.

In Russia, traps with maize or wheat have been used (Saplina, 1984) and gave better records than visual observations. A trap has been developed for USDA/PPQ (OEP P/EPPO, 1981) which combines a feeding attractant for larvae and a pheromone for adult males (Barak, 1989).

A complete survey protocol whereby the absence or presence of *Trogoderma* spp. (not Khapra beetle specific) can be verified, has been drawn up for Western Australia (Poole, 1999). The method consists of using sticky traps and a pheromone lure. Biolure <http://www.insectslimited.com/wbkbbiol>. However, these traps are placed in a suspended position, and therefore only flying *Trogoderma* are trapped. With the non-flying Khapra beetle not being able

to enter suspended traps, such traps show only the presence of other *Trogoderma* spp., results which may then be used to derive some estimates on Khapra catches in wall mounted traps. This information would be particularly useful, since (as mentioned before) distinguishing between Warehouse and Khapra beetle is a difficult and time-consuming task. As for targeted surveillance, the suspended trap can thus be used as an indicator of other *Trogoderma* spp., but any reference to Khapra beetle specific traps, implies the use of the **wall mountable type**, better known as the Biolure box trap.

Once Khapra beetle has been found, adjacent areas as well as areas suspect of being on the continued pathway (see next section) should be identified for targeted surveillance. Such surveillance needs to be auditable/quantifiable and designed in order to meet the standards as set by the trading partners. Results should be thoroughly data-based, and substituted with clear mapping of all *Trogoderma* catches. See APHIS (1984) for the survey procedures used in the United States Action Plan.

Taxonomic Tree

Domain: Eukaryota

Kingdom: Plantae

Phylum: Spermatophyta

Subphylum: Angiospermae

Class: Dicotyledonae

Order: Myrtales

Family: Myrtaceae

Genus: *Eucalyptus*

Species: *Eucalyptus*

S.N: *Eucalyptus camaldulensis*

Notes: *Eucalyptus camaldulensis* exhibits considerable morphological variation throughout its range, and consequently a number of infraspecific taxa have been described. Var. *camaldulensis* is the most widespread, and the only one occurring in the Murray-Darling Basin. For further discussion on morphological variation, Brooker *et al.* (2002). Chemical and genetic variation has also been recorded in *E. camaldulensis* (Doran and Brophy, 1990; Stone and Bacon, 1994; Butcher *et al.*, 2001).

Description

Australia, *E. camaldulensis* commonly grows up to 20 m tall and rarely exceeds 50 m, while stem diameter at breast height can reach 1-2 m or more. In open woodlands it usually has a short, thick bole which supports a large, spreading crown. In plantations, it can have a clear bole of up to 20 m with an erect, lightly-branched crown. The bark is smooth white, grey, yellow-green, grey-green, or pinkish grey, shedding in strips or irregular flakes. Rough bark may sometimes occupy the first 1-2 m of the trunk on *E. camaldulensis* var. *camaldulensis*. This species is described in many texts including Boland *et al.* (1984), Brooker and Kleinig (1983; 1990; 1994), Chippendale (1988), Doran and Turnbull (1997), and Doran and Wongkaew (1997). Juvenile leaves are petiolate, ovate to broadly lanceolate, up to 26 cm long and 8 cm broad, green, grey-green, or blue-green, slightly discolourous. Adult leaves are lanceolate to narrowly lanceolate, acuminate, lamina 8-30 cm long, 0.7-2 cm wide, green or grey-green, concolorous; petioles terete or channelled, 1.2-1.5 cm long. Inflorescence axillary, 7-11 (sometimes up to 13)-flowered; flowers white, peduncles slender, terete or quadrangular, 6-15 mm long; pedicels slender, 5-12 mm long. Buds pedicellate; hypanthium hemispherical, 2-3 mm long, 3-6 mm wide, operculum globular-rostrate (typical) ovoid-conical (var. *obtusa*) or, in subsp. *simulata*, horn-shaped like *E. tereticornis*, 4-6 mm long (up to 13 mm

long in subsp. *simulata*), 3-6 mm wide. Fruits are hemispherical or ovoid, 5-8 mm long and wide; disc broad, ascending; 3-5 exerted valves.

Life form

Eucalyptus camaldulensis is a perennial, single-stemmed, large-boled, medium-sized to tall tree to 30 m high (Bren and Gibbs, 1986), although some authors (Boland, 1984; Brooker *et al.*, 2002) record trees to 45 m. According to Jacobs (1955) river redgum could reach ages of 500 to 1000 years. Brooker *et al.* (2002) for further descriptive information.

Habitat

Eucalyptus camaldulensis commonly grows on riverine sites, whether of permanent or seasonal water (Brooker *et al.*, 2002). It is most extensive on grey heavy clay soils along river banks and on floodplains subject to frequent or periodic flooding, preferring deep moist subsoils with clay content (Costermans, 1989). It also lines the channels of sandy watercourses and creeks (Boland, 1984), commonly forming ribbon stands but sometimes extending over extensive areas of regularly flooded flats. It can also occur in the higher reaches of creeks in major valleys of hilly country (Cunningham *et al.*, 1981) and infrequently on the margins of salt lakes (CAB International, 2000).

Reproduction

Breeding system

The eucalypt breeding system is one of mixed mating with preferential outcrossing. Although eucalypts are commonly self-compatible, self-pollination generally results in a reduction in capsule production, seed yield and seedling vigour (House, 1997). Analyses of the breeding system of *E. camaldulensis* indicate a predominantly outcrossing mating system (CAB International, 2000).

Pollination

Pollination is mainly by insects but also by birds and small mammals (CAB International, 2000).

Flowering

Eucalyptus flowers in most years from late spring to mid-summer (July to February according to Brooker and Kleinig, 1999, December to February according to Boland, 1984). Flowering intensity is variable and unpredictable from year to year. About 45% of flowers fail to mature (Dexter, 1978).

Fruit seed

Fruit development and maturation time can be as short as four months (CAB International, 2000). Number of viable seeds per unit weight of a seed lot: mean 698,000/kg *Eucalyptus* species store little or none of their seed in the soil (McEvoy, 1992).

Uses (including ethnobotanical)

River red gum forests are historically and culturally important due to the number of significant Aboriginal sites they contain. Common relics include canoe and shield trees. Such trees show scars where the bark was removed (Dalton, 1990). The wood has been used for heavy construction, railway sleepers, flooring, framing, fencing, plywood and veneer manufacture, wood turning, firewood and charcoal production (Boland, 1984). Useful for shade, shelter and in windbreaks; deep-rooted, which allows grass growth right up to the base; bark is resistant to stock damage. For southeastern Australia, *E. camaldulensis* along with *Eucalyptus melliodora* (Yellow Box) and *Acacia melanoxylon* (Blackwood) are considered superior shade trees. It is also attractive as an ornamental for acreage plantings.

Medical use:

Volatile oils which are introduced into medical use contain 55- 70% lineol, plus lesser amounts of volatile aldehydes (Varro, *et al*; 1981). Essential oils of

Eucalyptus spp. were used as an antibacterial, antimicrobial and acaricidal agent (Bagherwl, 1999; Harkenthal, *et al*, 1999; and Lisin, *et al*, 1999).

The antioxidant activities of the volatile oil and the ethanol extract as well as that of the tree bark were evaluated by the thiocyanate method. The ethanol extract of *Eucalyptus* fruit exhibited considerable activity compared with butylatedhydroxyanisole and tertiary butylated hydroquinone. The high inhibitory effect of the fruit ethanol extract on linoleic acid after 12 days might be related to the higher ellagic acid content. (Al-Ghorab, *et al*, 2002).

Insecticidal activity:

The toxicity of leaves oil obtained from *Eucalyptus camaldulensis* by steam distillation was tested against the fourth larval instar of *Anopheles stephensi*. The LD₅₀ for the larvae was 113 ppm (Kumar and Dutta, 1987). *E. Camaldulensis* reduced the number of galls of the nematode *Melodogyne arenaria* and eggs masses by 70 – 85 and 81-89 %, respectively (Ibrahim, *et al* 1998). Also *E. camaldulensis* suppressed egg hatching of *M. arenaria* to varying extents, depending on the concentration used (Shahda, *et al*; 1998). *E. camaldulensis* powder mixed with rice at a rate of 1% by weight was effective in reducing the number of adults of *Sitotrogacerealella* emerging per 100g rice to 77 compared with 369 in the untreated rice; and prevented cross-infestation by *Rhyzopertha dominica* (Dakshinamurthy, 1988). In Sudan Mohagir, (2000) studied the effect of application of *Eucalyptus camaldulensis* on tree locust and it reduced the frequency of molting, gave high mortality, deformation and antifeedent effect. *E. camaldulensis*, also was installed in 8 areas of termite activity in different ecological zones during 1985 – 1986; observations recorded after a few months indicated that *E. camaldulensis* was very effective against termites (Hanif, *et al*, 1988).

Environmental Requirements

E. camaldulensis grows under a wide range of climatic conditions, from warm to hot and sub-humid to semi-arid. The following data pertain to the species' natural range, while Booth and Pryor (1991), Marcar et al. (1995) and Booth (1996) provide climatic profiles combining information from both natural and planted occurrences. Figures are given for the tropical northern variety (var. *obtusa*), and the temperate southern variety (var. *camaldulensis*). For the northern variety, the mean maximum temperature for the hottest month is in the range 28-40°C; the mean minimum for the coldest month is in the range 6-22°C; and the absolute minimum temperature has been reported as being in the range -3 to 6°C. For the southern variety, the mean maximum temperature of the hottest month is in the range 21-41°C; the mean minimum temperature for the coldest month is in the range 0-14°C; and the absolute minimum temperature has been reported as being in the range -5 to -7°C. Up to 40 frosts a year may be experienced in southern and inland areas which experience the lowest absolute minimum temperatures. The mean annual rainfall in the natural range of *E. camaldulensis* is mostly 250-600 mm, although a few areas receive up to 1250 mm, exceptionally up to 2500 mm, and some as little as 150 mm. In low rainfall areas *E. camaldulensis* relies on seasonal flooding and/or the presence of a high water table, such that minimum rainfall figures do not give a reliable indication of the tolerance of the species to drought. Depth and texture of the soil are also important factors in determining minimum rainfall for successful growth. Rainfall distribution varies from a winter maximum in southern areas to a monsoonal type in northern Australia, falling mostly between November and March. Rainfall variability is very high in inland regions with frequent long, dry spells, *E. camaldulensis* occurs on a variety of soil types. It is common on heavy clays in southern Australia, but more generally occurs on sandy alluvial soils in the north. It

infrequently occurs on the margins of salt lakes. It has been recorded growing on calcareous soils in South Australia (e.g. near Port Lincoln) and Western Australia (e.g. DeGrey and Greenough Rivers, and Wiluna) (Jacobs, 1981; Eldridge et al., 1993). Although mainly a tree of depositional or alluvial sites it sometimes extends to slopes at higher elevations, as in the Mt. Lofty Ranges near Adelaide, Australia.

Environmental Impact

Little specific information on the impact of *E. camaldulensis* on biodiversity is available; however, Henderson (2001) describes it as a habitat transformer. The species has been blamed in some countries (e.g. India and Thailand) for reducing soil water reserves, depleting soil nutrients, and other ecologically negative effects. Most impartial studies, however, have shown these criticisms to be wrongly directed at the plant rather than at the real causes of disharmony that are more socio-economic in nature (e.g. Raintree, 1991; ACIAR, 1992).

Prevention and Control

In southern Australia, changed grazing and flooding regimes appear to affect the post-dispersal survival of seeds (Meesonet *al.*, 2002). In an experiment, seed predation by ants was highest at sites grazed by cattle and Meesonet *al.*, (2002) concluded that a reduction in the frequency of flooding events was likely, through the interaction of livestock and seed predators to have reduced potential *A. camaldulensis* recruitment.

There is little information available on control of *E. camaldulensis* specifically, however, for some other invasive eucalypts (e.g. *E. cladocalyx*, *E. globulus*), the practice of digging out seedlings and young trees has been applied (Weber, 2003). Similarly mature trees of these species have been felled and the stumps treated with herbicide, and drilling stems and filling with herbicide is a further approach (Weber, 2003).

CHAPTER THREE

MATERIALS AND METHODS

3.1. Khapra beetle (*Trogoderma granarium*) rearing: -

Khapra beetle (*Trogoderma granarium*) adult including males and females were continuously feeding and it was resulted finally in formation of khapra beetle culture containing different development stages the third larval stage was the stage selected for running the experiment included in this study

3.2. Preparation of natural products powder

Cafour leaf were collected during 2016 from one location in shambat, the leaf was carefully crushed with a pestle and mortar the latter were ground by an electric blender into fine powder which was stored in a tightly closed glass jar and kept in the room temperature under tropical conditions until needed tests at each dosage.

3.3. Experiment Layout

The experiment was conducted in the laboratory in glass the objective of the experiment is to evaluate the anti-feedant and mortality effect of different concentration. Nine glasses were prepared for running this experiment. The experiment contains four treatment three different powder concentrations 2g- 4g- 6g in addition to the control.

3.4. Statistical analysis

Data were analysed using Analysis of Variance. Then means were separated using least Significant Difference

CHAPTER FOUR

RESULTS

The result of this Experiment showed in table (1).The leaves powder of *Eucalyptuscamaldulensis* gave high significantly different than the control after 3days and 7 days of exposure. While significant difference was observed between concentrations after the same periods of exposure.

The mortality of *Trogoderma granarium* larva were gradually increased by increasing of exposure time. After only 1 days the mortality reach 0% in leaf powder, and after 3days gave under than 20% mortality and after one week the treatment gave under than 20% mortality (13,33 and 10,00%), respectively. While the concentration 2% gave over than 20% mortality

These results gave clear indication that cafour powder could be an alternative method for control of *Trogoderma granarium*.

Table (1):percentage mortality of *Trogodermagranarium* larvae feed on stored sorghum seeds treated with different concentrations of *Eucalptuscamaldulensis* leaf powder after week:

concentration	Mortality %		
Treatment	24 hrs	72 hrs	Week
6.0%	0.0	26.67 ^a	13.33 ^b
4.0%	0.0	20.00 ^a	10.00 ^{bc}
2.0%	0.0	20.00 ^a	26.67 ^a
Control	0.0	00.00 ^b	00.00 ^c
F-cal		6.857	8.733
P-value		0.0133 [*]	0.0066 ^{**}
C.V%		15.83%	21.64%
Lsd _{0.05}		14.38	12.15

Value(s) sharing same superscript(s) in a column are not significantly different (P>0.05) according to Duncan Multiple Range Test.

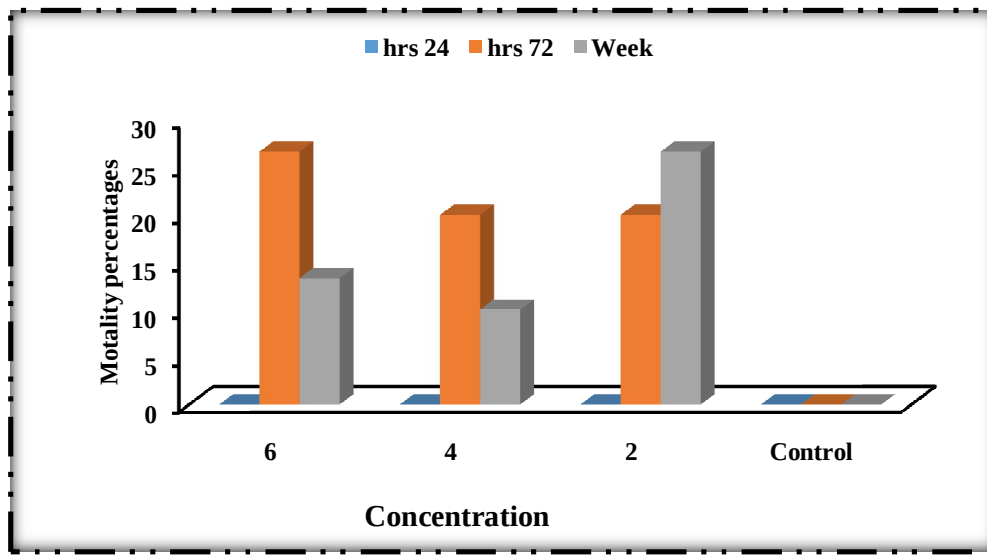


Fig.1. Main mortality percentages of *Trogoderma granarium* larvae treated with different concentrations of *Eucalyptus camaldulensis* leaf powder

CHAPTER FIVE

DISCUSSION

The use of insecticide to control insects cannot be eliminated; however, usage of pesticide has created many problems such as environmental pollution, toxicity, death to natural enemies and non-target organisms. Insect resistance resurgence of treated pests. A number of investigators have screened many plant extracts from different families for insect feeding detergency and growth inhibiting. Materials derived from some plants might have a better alternative with less likelihood of disrupting the ecological balance. The present study describes a number of experiments carried out under room conditions to investigate the repelling activity of *Eucalyptus camaldulensis* leaf powder against *Trogoderma granarium* adults. The investigation was extended to cover the efficacy of Cafour powder (Saeed, 2008).

On the fecundity, hatchability and adult emergence of *Trogoderma granarium* as well as to evaluate their insecticidal activity against test insect. Generally, all agents studied have repelling activity against test insect and their effects were less dose related. However, considerable variations in potency were noticed with Cafour powder being the best repelling and lethally agent.

The highest mortality percentages in this experiment showed in concentration 2% reached (26.67%) after one week, compared to untreated control.

In the untreated sorghum the infection rate was 50% during the period of the experiment (week) in a comparison with the treated one in which 0 infection had less difference according to the differentiation in the efficiency.

This study was in agreement to the toxicity of leaves oil obtained from *Eucalyptus camaldulensis* by steam distillation was tested against the fourth larval instar of *Anopheles stephensi*. The LD₅₀ for the larvae was 113 ppm (Kumar and Dutta, 1987). *E. Camaldulensis* reduced the number of galls of the nematode *Melodogyne arenaria* and eggs masses by 70 – 85 and 81-89 %, respectively (Ibrahim, *et al* 1998).

Conclusion

The cafour leaf powder was not so effective against khapra beetle

Recommendation

More studies are needed to determine active ingredients of cafour

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APPENDICES

Appendix (1)

ANALYSIS OF VARIANCE TABLE					
S. of var.	df	SS	MS	F-cal	P-value
Treatment	3	1200.000	400.000	6.857	0.0133
Error	8	466.667	58.333		

Coefficient of Variation = 15.83%

Duncan's Multiple Range Test: LSD value = 14.38 SE = 4.410

6.0% = 26.67a

4.0% = 20.00a

2.0% = 20.00a

0.0% = 0.000b

(Mortality leaf week)

ANALYSIS OF VARIANCE TABLE					
S. of Var.	df	SS	MS	F-cal	P-
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