UNIVERSITI PUTRA MALAYSIA

UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA SEED BEETLE, CALLOSOBRUCHUS MACILATUS (FABRICIUS) (COLEOPTERA : BRUCHIDAE)

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FP 2004 30

UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA SEED BEETLE, *Callosobruchus maculatus* (Fabricius) (COLEOPTERA: BRUCHIDAE)

By

MEKASHA CHICHAYBELU WESSENE

Thesis Submitted to the School of Graduate Studies, Universiti Putra Malaysia, in Fulfilment of the Requirements for the Degree of Doctor of Philosophy

July 2004

Dedicated to

my wife Fasika Hailu and my daughters Tsion Mekasha, Marta W/Senbet and the late Betselot Mekasha. To my father the late Chichaybelu Wessene, my mother Alemework Asfaw and my brother Fiseha Chichaybelu.

Abstract of thesis presented to the Senate of Universiti Putra Malaysia in fulfilment of the requirements for the degree of Doctor of Philosophy

UTILIZATION OF SOLAR HEAT FOR THE CONTROL OF COWPEA SEED BEETLE, *Callosobruchus maculatus* (Fabricius) (COLEOPTERA: BRUCHIDAE)

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July 2004

Chairman: Professor Dzolkhifli Omar, Ph.D.

Faculty: Agriculture

A survey, consisting of two hundred sample farmers, was conducted in major cool-season food legume growing regions of Ethiopia. Assessment of grain legume seeds collected from sample farmers' stores revealed the importance of adzuki bean beetle, *C. chinensis* (L.). Storage pests were more serious in mid altitude than highland areas. Farmers realized the negative effect of storage insect pests on marketability, consumption quality and viability of legume seeds. Hence, development of economically feasible and environmentally friendly control options is needed.

Biology of *C. maculatus* was studied on adzuki bean seeds in Malaysia at UPM. Mated female bruchid laid 61.8 eggs on average in its life with reproductive effort of 11.6. Eggs had average incubation period of 4.6 days and mean hatchability rate of 77.9%. Four larval instar stages were recognized. The insect had mean developmental period of 27.8 days with adult emergence rate of 62.0%. Number of eggs had strong negative relation to age of female bruchid while developmental period had positive relation.

Obtuse-base-angle box heaters glued from inside with aluminum foil had better ability in trapping solar energy where 118^{o} base-angle box had significantly high performance. Square box heaters painted black from inside trapped higher solar energy with better performance of boxes of 10 cm height, though not as capable as the obtuse-base-angle box heaters. The different glazing thicknesses and glazing layers did not show significant effect on the extent of trapped energy. Box heater of 118^{o} base angle, glued from inside with aluminum foil was, therefore, promoted for further evaluation of the effect of heating on *C. maculatus*, due to its better performance in trapping solar energy.

Effect of heat treatment on *C. maculatus* and adzuki bean seed moisture content and germination was evaluated. Exposure of the various developmental stages of *C. maculatus* to heat for up to 45 minutes raised the temperature between and within the seeds well in excess of the lethal level and resulted in complete control. Treatment of adzuki bean seeds with heat for up to one hour did not significantly affect seed viability. Though there was no significant difference, about 18.6% and 27% loss in seed viability resulted from seeds treated for 30 and 60 minutes, respectively, should not be undermined. Hence,

adzuki bean seeds meant for planting should not be heat treated to control storage insect pests. However, heat treatment had no much effect on seed moisture content.

Assessment on the effect of seed layer thickness on the efficacy of heat treatment against *C. maculatus* revealed that up to 3 cm thickness of adzuki bean seed can be treated at a time, as neither adult bruchids survived heat treatment nor emerged later. Therefore, solar heating of infested adzuki bean seeds using the aforementioned box heater around noon for an hour can give effective control of *C. maculatus.*

Abstrak tesis yang dikemukakan kepada Senat Universiti Putra Malaysia sebagai memenuhi keperluan untuk ijazah Doktor Falsafah

PENGGUNAAN HABA DARIPADA TENAGA SURIA UNTUK MENGAWAL KUMBANG BIJIRIN KACANG DUDUK, *Callusobruchus maculatus* (Fabricius) (COLEOPTERA: BRUCHIDAE)

Oleh

MEKASHA CHICHAYBELU WESSENE

Julai 2004

Pengerusi: Profesor Dzolkhifli Omar, Ph.D.

Fakulti: Pertanian

Satu bancian yang terdiri seramai 200 petani telah dijalankan di kawasan utama penanaman kekacang musim sejuk di Ethiopia. Penilaian terhadap bijirin kekacang simpanan yang di perolehi daripada sampel petani yang di banci menunjukkan pentingnya kumbang kacang merah, *C. chinensis* (L.). Perosak simpanan adalah lebih teruk di altitud pertengahan di bandingkan dengan kawasan tanah tinggi. Petani sedar kesan buruk akibat serangan perosak simpanan terhadap pemasaran, kualiti remekanan dan keboleh hidip biji kacang. Oleh yang demikian pembentukan suatu kaedah pengawalan yang murah dan mesra alam adalah diperlukan.

Biologi *C. maculatus* telah dikaji dengan menggunakan biji kacang merah. Dalam jangkahayat kumbang betina bruchid yang sudah mengawan purata 61.8 biji telur di hasilkan dengan keupayaan membiak 11.6. Purata jangkamasa pengeraman telur ialah 4.6 hari dan purata peratus penetasan ialah 77.9. Terdapat 4 instar larva. Purata jangkamasa tumbesaran adalah 27.8 hari manakala kadar kemunculan dewasa ialah 62%. Bilangan telur mempunyai korelasi negatif dengan umur kumbang betina manakala korelasi dengan jangkamasa tumbesaran adalah positif.

Alat pemanas berbentuk sudut dasar cukah yang dilapik dengan kepingan aluminium mempunyai keupayaan yang baik didalam memerangkap tenaga suria di mana kotak bersudut 118^{o} memberi prestasi yang signifikan. Kotak pemanas berbentuk 4 segi empat sama yang dicat hitam di bahagian dalam memerangkap tenaga suria yang tinggi dengan prestasi yang baik di tunjukkan oleh kotak yang tingginya 10 cm, walaupun tidak sebaik alat manas sudut dasar cukah.

Bahan pengupaman yang berbeza ketebalan dan lapisan tidak menunjukkan kasan yang nyata didalam memerangkap tenaga suria. Kotak pemanas bersudut 118^{o} yang gam dengan kepingan aluminium telah dipilih untuk kajian seterusnya bag menentukan keberkesanannya untak mengawal *C. maculatus*. Ini disebabkan alat ini telah didapati mempunyai keupayaan yang tinggi memerangkap tenaga suria.

Kesan rawatan haba terhadap *C. maculatus* dan kandungan air dan kesuburan kacang merah telah dikaji. Pendedahan haba terhadap berbagai peringkat hidup *C. maculatus* selama 45 minit telah meningkatkan suhu di antara dan di dalam biji tanpa melebihi tahap maut bijirin dan seterusnya mengakibatkan kawalan serangga yang sepenuhnya. Rawatan haba terhadap kacang merah selama 1 jam tidak mempengaruhi secara nyata, keboleh hidup biji. Walaupun tidak tendapat perbezaan bererti, keboleh hidup biji yang menurun 18.6% dan 27% masing-masing setelah dirawat selama 30 dan 60 minit tidak seharusnya di ketepikan. Oleh yang demikian biji kacang merah yang hendak dijadikan benih tidak seharusnya diberi rawatan haba. Walau bagaimanapun, rawatan haba tidak memberi kesan terhadap kandungan air biji.

Penilaian ke atas kesan ketebalan lapisan biji kacang merah terhadap efikasi rawatan haba bagi mengawal *C. maculatus* menunjukkan lapisan kacang merah setebal 3 cm boleh dirawat pada satu masa, di mana dewasa bruchid tidak mandir dan tidak menjelma. Oleh itu rawatan haba suria terhadap kacang merah dengan menggunakan alat pemanas sudut dasar cukah pada waktu tengah hari selama 1 jam boleh mengawal *C. maculatus*.

ACKNOWLEDGMENTS

I would like to extend my heart felt gratitude to my major supervisor Prof Dr. Dzolkhifli Omar, and supervisory committee members; Prof Dr. Yusuf Sulaiman; Assoc. Prof Dr. Rita Muhamad, Mrs. Noorma Osman and Dr. Legesse Dadi, for their indispensable assistance and advice in the accomplishment of this work. I am grateful to the Ethiopian Agricultural Research Organization for sponsoring my study.

I further extend my appreciation to the Ethiopian students at Universiti Putra Malaysia for their unreserved all time help. I would also like to thank Mr. Jarkasi Sarbini for the support he rendered in facilitating conditions during my research.

I certify that an Examination Committee met on 22nd July 2004 to conduct the final examination of Mekasha Chichaybelu Wessene on his Doctor of Philosophy thesis entitled "Utilization of Solar Heat for the Control of Cowpea Seed Beetle, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae)" in accordance with Universiti Pertanian Malaysia (Higher Degree) Act 1980 and Universiti Pertanian Malaysia (Higher Degree) Regulations 1981. The Committee recommends that the candidate be awarded the relevant degree. Members of the Examination Committee are as follows:

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DECLARATION

I hereby declare that the thesis is based on my original work except for the quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted to any other degree at UPM or other institution.

MEKASHA CHICHAYBELU WESSENE

Date: 11 August 2004

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CHAPTER 1

INTRODUCTION

The importance of pulses (legumes) lies in their food value as major source of protein, energy, minerals, vitamins and roughage in addition to their miscellaneous uses in animal feed, soil fertility maintenance and industry. In many tropical developing countries of the world, pulses supply a high proportion of the plant proteins which are not only the main, but also the cheapest source of protein in areas where animal protein are scarce and too expensive for a large proportion of the population (Okigdo, 1978). In addition to the above-mentioned uses Telaye *et al.* (1994) reported that stalks of pulses are used as a source of fuel for cooking purposes.

Preserving the harvested crop without loss or damage is a problem of every nation. In tropical climate, deterioration of stored material, aided by insect damage and moulds, can be rapid (Hill, 1997). The wide variety of materials that humans accumulate and store in containers ranging from large bins to small boxes present conducive environmental conditions for certain insects thrive, essentially free of any natural enemies (Romoser and Stoffolano, 1998). In developing countries much produce is kept in on-farm stores in small quantities under quite primitive conditions that are liable for insect pest infestation. Hence destruction of food by stored grain insect pests is one of the major factors responsible for the low levels of subsistence in many tropical countries.

Most representatives of stored-product insect pests can reproduce and infest all round the year (Zakladni and Ratanova, 1987). Moreover, most of this group of pests have short developmental periods and thus have several generations a year. On the other hand, fluctuations in temperature and moisture content in the store are low and hence stored grain pests suffer less from extreme conditions. Therefore, the high fecundity and quick development of these pests can, under optimal conditions, result in a catastrophically fast increase in their population.

Hence, the direct feeding of insect pest on stored grains results in weight losses that can end up in the commercial loss of the whole grain. These pests also cause loss in quality of stored grains. Loss of seed viability, among other factors, may be caused by insect infestation where insects that selectively attack the germ will cause greater loss than others. Infestation generally results in dissatisfied customers and related marketing problems that develop from a poor reputation in marketing channels. Most unfortunate consequence of not managing grain properly is the loss of money, time and effort to produce grain.

Bruchids (Coleoptera: Bruchidae) are among the important constraints in grain legume production. They cause considerable quantitative and qualitative losses to stored legumes. Due to this, farmers are often reluctant to grow legumes, as they have to dispose of their produce immediately after harvest, even though the market price may not be remunerative at that time (Chauhan and Ghaffar, 2002).

Synthetic pesticides are currently the method of choice to protect stored grain from insect damage. However, their widespread use has led to the development of pest strains resistant to insecticides and pest resurgence (Subramanyam and Hagstrum, 1995; Pedigo, 1999). Moreover, they are hazardous to other species than those they are intended to control and unsafe to the environment (Kitch *et al.*, 1992; Shaaya *et al.*, 1997). On the other hand, the utilization of such products is less feasible for low resource farmers. These factors call for a demand for safer and cheaper alternatives to be integrated in the management of the pests.

One technique that has been used successfully for many years against stored product pests is the use of extreme temperature. The potential of using solar energy in controlling storage insect pests through heating of grains in various types of solar heaters has been reported earlier (Nakayama *et al.*, 1983; Murdock and Shade, 1991; Kitch *et. al.*, 1992; Mohammed *et al.,* 2001;