STORAGE GRAIN PEST SURVEY AND EFFICACY OF VARIOUS ESSENTIAL OILS AGAINST CHICKPEA PULSE BEETLE (*Callosobruchus chinensis* L.) IN LABORATORY CONDITION AT RAMPUR, CHITWAN

HARI PRASAD SUBEDI

NOVEMBER 2015

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HARI PRASAD SUBEDI

THESIS
SUBMITTED TO THE
AGRICULTURE AND FORESTRY UNIVERSITY
FACULTY OF AGRICULTURE
RAMPUR, CHITWAN
NEPAL

IN PARTIAL FULFILLMENT OF THE
REQUIREMENTS FOR THE
DEGREE OF

MASTER OF SCIENCE IN AGRICULTURE
(ENTOMOLOGY)

NOVEMBER 2015

CERTIFICATE

This is to certify that the thesis entitled **"STORAGE GRAIN PEST SURVEY AND EFFICACY OF VARIOUS ESSENTIAL OILS AGAINST CHICKPEA PULSE BEETLE (*Callosobruchus chinensis* L.) IN LABORATORY CONDITION AT RAMPUR, CHITWAN"** submitted in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture**with major in **Entomology** of the Postgraduate Program, Agriculture and Forestry University, Rampur, is a record of original research carried out by **Mr. HARI PRASAD SUBEDI, Id. No. ENT-06-M-2013,** under my supervision, and no part of the thesis has been submitted for any other degree or diploma.

_____

Asst. Prof. Min Raj Pokhrel
Chairman of the Advisory Committee
Department of Entomology
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The thesis attached herewith, entitled **"STORAGE GRAIN PEST SURVEY AND EFFICACY OF VARIOUS ESSENTIAL OILS AGAINST CHICKPEA PULSE BEETLE (*Callosobruchus chinensis* L.) IN LABORATORY CONDITION AT RAMPUR, CHITWAN"** prepared and submitted by **Mr. HARI PRASAD SUBEDI,** in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture (Entomology),** is hereby accepted.

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DEDICATED TO MY
BELOVED PARENTS

ACKNOWLEDGEMENTS

I would like to express my profound sense of gratitude and admiration to Assistant Professor Mr. Min Raj Pokhrel, chairman of my advisory committee, Department of Entomology, Agriculture and Forestry University, Rampur for his encouragement, continuous guidance and valuable suggestions from very initial stage of research proposal preparation, field survey, laboratory research to the preparation of thesis report.

It gives me mammoth pleasure to express my reverential regards to Prof. Resham Bahadur Thapa, Ph.D., Department of Entomology, Agriculture and Forestry University, Rampur, Chitwan and Assistant Professor Mr. Sundar Tiwari, Department of Entomology, Chairman of the Department, and members of advisory committee for their encouragement, supervision and constant guidance throughout the research period and preparation of this manuscript.

My sincere gratitude is extended to Prof. Dilli Ram Baral, The Dean and Prof. Bishnu Raj Ojha (Assistant Academic Dean) for the academic environment, constructive suggestions and valuable ideas.

I owe my sincere gratitude to the CARITAS NEPAL for providing fund for conducting the research and for the preparation of thesis. Special thanks goes to Mr. Chintan Manandhar, Programme Officerand Mr. Tej Khadka, Field Technicians of CARITAS NEPAL, for necessary arrangement and the support during field survey.

I am greatful to many colleagues specially Roshan Subedi, Sudhir Paudel, Ramji Prasad Bhattarai, Indra Bahadur Thapa, Anil Paudel, Homan Regmi,Anil Poudel for their encouragement and invaluable support during my study period. A special thanks goes to Dipa Paudel for her encouragement, support and inspiration during my study period and immense thanks extends to Sridhar Khanal, Suvas Kumar Jha, Ankur Paudel, Pankaj Kasyap, Milan Gaire, Yubraj Dhakal, Bhola Gautam, Anantamani Bhattarai, Sushil Neupane Dipak Timilsena, Susmita Subedi Madan Mani Sapkota, Babita Tiwari, Kusum Pandey for their support, encouragement during experiment. I want to thank Mr. Santosh Tamang and Mr. Manoj Tamang of Rose cyber for their help during thesis editing and printing.

I would like to express special thanks and my heartiest gratitude and respect to my beloved parents Mr. Padam Lal Subedi and Mrs. Batuli Subedi for their utmost cooperation, sacrifice, inspiration, heartfelt blessing and encouragement during my entire

study period. I would like to express my profound sense of gratitude and cordial indebtedness to my beloved brothers Ganesh and Kushal and similar thanks to all my nears and dears for their continuous love, inspiration and moral support.

Hari Prasad Subedi

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

ACRONYMS

@	At the Rate of
^0C	Degree Centigrade
AFU	Agriculture and Forestry University
Avg	Average
%	Percent
CO_2	Carbon Dioxide
CV	Coefficient of Variation
DAT	Days After Treatment
Dm	Diameter
gm	Gram
GP	Germination Percent
IPM	Integrated Pest Management
LSD	Least Significant Difference
Max	Maximum
Min	Minimum
ml	Milliliter
No	Number
P	Probability
ppm	Parts per Million
RH	Relative Humidity
SGP	Storage Grain Pest
SEM	Standard Error of Mean
Temp	Temperature
Var	Variety

ABSTRACT

Name: Hari Prasad Subedi
Id. No.: ENT-06M-2013
Semester and year of admission: First, 2013
Degree: M.Sc.Ag.
Major subject: Entomology
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A research on ecofriendly methods of managing chickpea pulse beetle (*Callosobruchus chinensis* L.) was conducted by exploring farmers'practices by doing storage grain pest survey and a laboratory experiment for testing nine treatments against chikchpea pulse beetle. The first part of the research, storage grain pest survey was carried out in three VDCs, Ramghat, Latikoili and Lekhgaun of Surkhet during 2014-2015 using pretested structured questionnaire. Fifteen households from each of the three VDCs were purposively selected. Rice, wheat, maize, chickpea, pea and lentil were found to be the major food grains damaged by storage pests. The bruchids were found to be major storage pests followed by lentil beetle, grain moth and grain weevil in that area. Chemical pesticides were found to be the most popular means but were getting ineffective and unsafe. Farmers were found to be using botanicals as the alternative methods. All most all the farmers mentioned storage pest infestation has increased over last 10-15 years and 47 % farmers mentioned they observed the storage pests even in cooler months. The second part of the research was carried out in the entomology laboratory of Agriculture and Forestry University, Rampur, Chitwan from March to June, 2015. The experiment consisted of nine treatments which were replicated thrice and laid out in Completely Randomized Design (CRD). The effects of nine treatments (Neem oil @ 3ml/kg, Clove oil@ 2ml/kg, Citronella oil @ 2.5ml/kg, Mentha oil@ 2ml/kg, Eucalyptus oil@3ml/kg, commercial Bojho oil@1ml/kg, French basil oil@2ml/kg, Malathion@ 1gm/kg, and Control) were evaluated against pulse beetle using ½ kg chickpea seeds in 2 kg capacity metal bins as the experimental unit. Among the treatments, the mortality of adult bruchids was significantly higher in chickpea seed treats with Citronell oil (27.67%) followed by Malathion dust (27.33%), Mentha oil (26.67%) and Eucalyptus oil (24.33%). Egg counts on 15, 45 and 75 days after treatment (DAT) were also recorded lowest in chickpea seed treated with Citronella oil(4.00, 5.00, 4.33 eggs/50seeds) in all the dates of data recording followed by Mentha oil (4.33, 6.66, 6.00eggs/50 seeds) and Eucalyptus oil (9.66, 13.00, 12.33 eggs/50 seeds), respectively. Interstingly, Malathion dust found effective for causing adult mortality (27.33%) has reduced effect on next generation adult emergence 81.00 and

108.70 at 45 DAT and 75 DAT respectively. Clove oil and Neem oil were also less effective with maximum egg counts and adult emergence. Thus among all the oils used Citronella oil, Mentha oil and Eucalyptus oils were found to be most promising in protecting grain damage by bruchids and in maintaining optimum seed quality up to the 3 months of storage. Fumigant toxicity of essential oils used as in the experiment were with toxicity order from higher to lower as Eucalyptus oil > Citronella oil > Mentha oil > Clove oil > Bojho oil >French basil oil > Neem oil. Therefore, these essential oils found to be most effective alternatives for the management of chickpea pulse beetle (*Callosobruchus chinensis* L.) in comparison to chemical pesticides.

Asst. Prof. Min Raj Pokhrel	Hari Prasad Subedi
Major advisor	Author

शोध-सार

नाम : हरि प्रसाद सुवेदी
सत्रान्त तथा भर्ना वर्ष : प्रथम, २०७०
मुख्य सल्लाहकार : उप-प्रा. मिन राज पोखेल

परिचय पत्र नं.: ईएनटी-०६-एम-२०१३
उपाधि : कृषि स्नातकोत्तर
विभाग : कीट विज्ञान

संचित अनाजका शत्रुको सर्वेक्षण र चनाको खपटेको विरुद्धमा विभिन्न उपयोगी तेलहरुको प्रभावकारिता अध्ययन दुई भागमा गरिएको थियो जसमा संचित अनाजका शत्रुको सर्वेक्षण र चनाको खपटेको व्यवस्थापनको लागि ९ वटा उपचार विधिहरुलाई प्रयोगशालामा परिक्षण गरिएको थियो। संचित अनाजका शत्रुको सर्वेक्षण सुर्खेत जिल्लाको तीनवटा गाविसरामघाट, लाटिकोईली र लेकगाँउमा माघ २०७१ मा गरिएको थियो भने प्रयोगशालामा अनुसन्धानात्मक परिक्षण कृषि तथा वन विश्वविद्यालय, रामपुर, चितवनमा बैशाखदेखि असार २०७२ मा गरिएको थियो । भण्डारणमा लाग्ने कीरासम्वन्धी सर्वेक्षणको उद्धेश्य अनुरुप छनौट गरिएका प्रत्येक गाविसका १५ वटा घरधुरीमा अन्तरवार्ता र लक्षित समुह छलफलद्धारा अध्ययन गरियो। त्यस अध्ययनवाट धान, गहु,मकै, चना, मुसुरो र केराउ उक्त क्षेत्रका मुख्य वालीहरु भएको पाईयो भने गेडागुडि वालीको भण्डारणमा चनाको खपटेप्रमुख कीराकोरुपमा पाईयो र उक्त किराको व्यवस्थापनकालागि रासायनिक विषादीको प्रयोग धैरै पहिले देखिनै गर्दै आएकोमा अहिले विषादीले राम्रो काम नगरेको र स्वास्थ्य तथा वातावरणमा पनि प्रतिकुल असर परेकोले किसानहरु वानस्पतिक विषादी तर्फ आर्कषित भएको पाईयो। यसका साथै जलवायुमा भएको परिवर्तनले गर्दा भण्डारणमा लाग्ने कीराको प्रकोप बढेको र चिसो महिनामा पनि प्रकोप देखिन लागेको कुरा अध्ययनवाट देखियो । चनाको भण्डारणमा लाग्ने खपटे व्यवस्थापनमा विभिन्न वनस्पती तेलको किटनाशक क्षमता अध्ययन अनुसन्धान प्रयोगशालामा गरिएको थियो । त्यस अध्ययनमा जसमा ७ वटा वनस्पति तेल (निम तेल ३ मिली प्रति केजी, ल्वाङको तेल २ मिली प्रति केजी. सिटोनेला तेल २.५ मिली प्रति केजि, पुदिनाको तेल २ मिली प्रति केजि, मसलाको तेल ३ मिली प्रति केजि, बोझोको तेल १ मिली प्रति केजि, तुलसीको तेल २ मिली प्रति केजि), मालाथियनको धुलो (१ ग्राम प्रति केजि) र विना उपचार सहित जम्मा ९ थरीका उपचार विधिहरुलाई ३ पटक दोहोऱ्याइएको थियो । अनुसन्धानमा प्रयोग गरिएका ८ वटा कीटनाशक पर्दाथहरु मध्ये सिट्रोनेला तेल(२७.६७ प्रतिशत) लगायत पुदिना तेल(२७.६७ प्रतिशत), मसला तेल(२४.३३प्रतिशत) र मालाथियन धुलो (२७.३३प्रतिशत) उपचारीत दानामा वयस्क खपटेको अत्याधिक मरणशिलता पाइयो । साथै उपचार विधिहरु वाट उपचार गरेको क्रमश १५, ४५ र ७५ दिनमा अण्डाको गणना पनि सिट्रोनेला तेल(४.००, ५.००, ४.३३ अण्डा प्रति ५० दानामा) लगायत पुदिना तेल (४.३३, ६.६६, ६.००अण्डा प्रति ५० दानामा), मसला तेल(९.६६, १३.००, १२.३३अण्डा प्रति ५० दानामा) उपचारित चनाको दानामा सुरुदेखि अन्तसम्म न्युन पाईयो। मालाथियन धुलोवाट उपचारित चनामा वयस्क ब्रुकिडको मरणशितला बढि भएपनि अण्डा गणना र वयस्क उत्पादनमा उक्त विषादी प्रभावहिन सरह सिद्ध भयो । यसका साथै निम तेल, ल्वाङ तेल, वोझो तेल र तुलसी तेलवाट उपचारीत चनामा वयस्क मरणशिलता मध्ययम पाइयो भने अण्डाको गणना र वयस्क उत्पादन हेर्दा निम तेल प्रभावहिन रहेको पाइयो । वीउमा पुगेको हानी तथा तौल घट्ने क्रमको अध्ययन गर्दा सिट्रोनेला तेल (१.६७ , ०.२८), पुदिना तेल (२.३३ , ०.३९), मसला तेल(३.३३,

०.७३) द्धारा उपचारित दानामा ७५ दिनको अन्तमा न्युनतम प्रतिशत वीउ हानि र शुन्य प्रतिशत वीउको तौल घटेको पाइयो भने ती उपचारीत वीउको चिस्यान र उमारशक्ति पनि अधिकतम कायम राखेको पाईयो । यसका साथै अध्ययनमा प्रयोग गरिएका तेलहरुको विषाक्तता पनि परिक्षण गरिएको थियो र जसमा विषाक्तताको क्रमश : मसला तेल>सिटोनेला तेल>पुदिना तेल>ल्वाङ तेल>वोझो तेल>तुलसि तेल>निम तेल रहेको थियो । यस अध्ययनवाट चनामा लाग्ने खपटेको व्यवस्थापनमा सिट्रोनेला तेल, पुदिना तेल, मसला तेल लाई क्रमश : सवै भन्दा बढी प्रभावकारी विकल्पको रुपमा पहिचान गरियो । अन्तमा परिक्षित वनस्पतिक तेलहरुलाई विभिन्न दलहन वालीको भण्डारणमा लाग्ने ब्रुकिड व्यवस्थापनको लागि प्रयोग गर्न सकिन्छ । जुन वातावरण मैत्रि हुनेछन् र रासायनिक विषादीको प्रयोग, यसवाट हुने नकारात्मक असरलाई घटाउन सकिने छ । यसको प्रभावकारीतावारे आउँदो दिनहरुमा अझ बढी अनुसन्धान हुदै जाँदा अझ बढी उपयोग बढ्न सक्ने देखिन्छ ।

उप-प्रा. मिनराज पोखेल
मुख्य सल्लाहकार

हरि प्रसाद सुवेदी
लेखक

1 INTRODUCTION

1.1 Background

Grain legumes are the key component of various cropping systems in Nepal as are important in human nutrition and sustainability of farming (Pandey, Yadav, Sah, Pande, & Joshi, 2000). The legume crops plays important role in enhancing the soil fertility by symbiotic nitrogen fixation. Pulses comprise the major part of the dietary protein for majority of poor as pulses are cheaper to animal protein sources. Crop residues and by-products are valuable as fodder, feed and firewood. In 2009, major pulses export and import of Nepal were of US$ 75,459,000 and US$ 29,184,000, respectively (FAO, 2011).

In the world, pulses or grain legumes are grown in 69.29 million ha with production of 64.0 million tons and productivity of 924 kg/ha during 2009 (FAO, 2010). India is the largest grower with 30% share in area and 23% share in production. Nepal contributes about 0.4% of world pulse area and production (Shrestha, Neupane, & Adhikari, 2011). Diverse climate and environmental conditions of Nepal offer opportunities for growing many species of grain legumes. In Nepal, pulses occupies 10% of total cultivated area and ranks fourth in area after rice, wheat and maize, and grown in 319,472 ha with production and productivity of 262,357ton and 821 kg/ha, respectively (MOAC, 2010). In recent year, the area and productivity has been slowly increasing, which increased to 334323 ha of crop land with production of 319769.8 ton and productivity of 956kg/ha (Year Book, 2012).

Globally chickpea is the third most important pulse crops mainly grown in the developing countries by resource-poor farmers in drought prone areas and on degraded soils (Joshi, Rao, Gowda, Jones, Silim, Saxena, & Kumar, 2001) and also one of the major legumes grown in Nepal. It is principally grown in the terai and inner terai in rainfed areas after rice and maize crops. It is traditionally grown either as a sole crop or as a mixed crop with mustard, wheat and/ or linseed on marginal lands with poor management (Pande*et al.*, 2005).

Among many other production constraints, insect pests are ranked third based on losses and the storage losses is estimated to be 9% in developed country to 20% or more in developing country (Philips & Throne, 2010). The pulse beetles (*Callosobruchus chinensis* L.) (Coleoptera: Curculionidae) is a major economically important pests of grain legumes in tropics (Talukder & Howse, 1994; Park, Kim, & Ahn, 2003). They are present in all the tropical and subtropical climates and attack a wide range of grain legume species

(Southgate, 1978; Talekar, 1988). The pulse beetle, *Callosobruchus chinensis*L. is the major pests of stored pulse grains in storage causing 15-20% losses in storage throughout the world (Kumar, Lodha & Singh, 2003). *Callosobruchus* causes seed weight loss, decreases germination potential and reduces commercial value of the seeds (Casewell, 1981).

To manage this serious pest, various physical and chemical pest management methods have been employed globally. Different synthetic fumigants developed and used to control this pest in storage are found to leave residues in/on grains and beetles have found to develop resistance against Ethylene-di-bromide (EDB) and aluminium phosphide during storage (Bond, 1984; Zettler & Cuperus, 1990; Zettler & Keever, 1994).

In Nepal, pesticides are most intensively applied on vegetables (Pokhrel, 2015), high value crops, such as fruits, mustards and cotton. Similarly, the farmers use chemical pesticides in stored product for easy and immediate control of storage pests. The most commonly used pesticide in storage is aluminium phosphide (Pandey, Ghimire, Sharma, & Gurung, 1996). There are nearly 1500 pesticide poisoning related death annually in the country over the last five years (Pokhrel, 2015) Majority of cases are due to intentional poisoning and a significant number of accidental poisoning is with the use of storage pesticides(CID, 2014).

Until recently, control of bruchids is heavily relied on the use of chemical pesticides. Moreover, the chemical based control measures likely to be effective only for short run. It is now widely known that the chemical method has several problems, which include health hazards to the users and grain consumers. It causes residual toxicity, environmental pollution and development of pesticide resistance. Thus, there is an urgent need to develop safe alternatives that have potential to replace toxic fumigants, yet are simple and convenient to use.

The plant products with insecticidal properties are becoming attractive alternatives to the synthetic, dangerous and more expensive insecticide used in developing countries (Rajpakse, Senanayake, & Rathasekara, 1998). On storage, most farmers do not treat crops with pesticides (Golob, 1994). Before the invent of the synthetic pesticides, local pesticidal plants were the major source of pest control against the pest of field crops as well as in storage. In the world, as many as 2400 plants species have been recorded that have pesticidal properties and biological activity against a wide range of pests (Grainage and Ahmed, 1988).

Therefore, a research was conducted to seek plant derivatives as the alternatives of chemical pesticides. Few essential oils with insecticidal properties and derived from plant sources were tested in the laboratory.

1.2 Objectives

The general objective of this study is to test the efficacy of various essential oils in chickpea pulse beetle (*Callosobruchus chinensis* L.) management as an alternative of chemical methods for sustainable pest management, food and environmental safety.

The following were specific objectives of the research:

- To know the status of major storage pest in different food grains in Surkhet condition
- To document farmer's practices in grain storage, storage grain pest management in farmer's condition and their perception on effects of climate change on storage pest infestation
- To test the efficacy of selected essential oils for management of chickpea pulse beetle in laboratorycondition

2 LITERATURE REVIEW

2.1 Importance grain legume

Agriculture is the main source of income and livelihood of 66% of rural population in Nepal (MoAC, 2009), with about 80% of population depend on subsistence farming, and have major concerns on household food security and poor nutrition (FAO, 2009).FAO food deprivation data 2005-07 for Nepal showed that 4.5 million people live under the condition of malnourishment (FAOSTAT, 2011).

Cereal crops are the staple food and contribute major share in area and production. Growing cereal crops year after year or intensive cereal production (short duration paddy, spring maize) systems have led to the degradation soil fertility, soil health, pest disease dynamics and soil erosion. Pulses (grain legumes) are important in terms of nutrition and subsistence farming. It plays role in enhancing the soil fertility by symbiotic nitrogen fixation. Pulses supply the major part of the dietary protein (20-25% protein by weight, which is 2-3 times that of wheat and rice) for majority of poor who cannot afford expensive animal protein and vegetarians. Crop residues and by-products are valuable as fodder, feed and firewood. In 2009, pulses (excluding soybean) export and import were of US$ 75,459,000 and US$ 29,184,000, respectively (FAO, 2011).

Grain legume constitute key component of various cropping system of Nepal. Pulses are ideal food grains for crop diversification, soil nitrogen economy, suitability to multiple and intercropping and adaptability to marginal lands. After cereal, grain legumes are the most important crops in many parts of the world, especially Southeast Asia, where animal protein is scarce and they provide a large proportion of the protein requirement (COPR, 1976).

In world, pulses or grain legumes (solely harvested for dry grains) are grown in 69.29 million ha with production of 64.0 million ton and productivity of 924 kg/ha (FAO, 2010) during 2009. India is the largest grower (30% share in area), producer (23% share in production) and consumer. Nepal contributes about 0.4% of world pulse area and production. Diverse climate and environmental conditions of Nepal offer opportunities for growing many species of food legumes. Grain legumes research received relatively little attention in Nepal as the primary need is on assuring food supply for the increasing population. In Nepal, pulses (includes soybean) occupies 10% of total cultivated land,

ranking fourth in area after rice, wheat and maize. Grain legumes are grown in 319,472 ha with production and productivity of 262,357 and 821 kg/ha, respectively (MOAC, 2010).

Grain legume rank fourth in area and production after rice, maize and wheat and occupy more than 334323 ha of crop land with production of 319769.8 ton and productivity of 956kg/ha (Year book, 2012).

Gram or chickpea (*Cicer arietinum* L.), a member of family Fabaceae, is an ancient self-pollinated leguminous crop, diploid annual (2N=16 chromosomes) grown since 7000BC, in different area of the world (Singh, Pundir, & Robertson, 2007).The common name used for chickpea are Bengal gram (India), Garbanzo (Latin America), Hommes, Hamaz (Arab world), Nohund, Lablabi (Turkey), Shimbra (Ethiopia) and Chana in Pakistan. It has been growing in Turkey since nearly 7400 years ago. Turkey is considered as the oldest cultivated land for this pulse crop. It provides high quality protein and considered to be the best food for vegetarian population in south Asia, West Asia and Southern European countries (FAO, 2005).

Chickpea (*Cicer arietinum* L.) locally called Chana covers about 3% of the total area and production (MoAC, 2010). There has been a sharp reduction in area and production of chickpea due to Botrytis gray mold disease (BGM) and *Helicoverpa* podborer (Pokhrel, Neupane, & Shrestha, 1999).

Chick pea is used in range of different preparations in our cuisine and has a good source of energy, i.e. 416 calories/100 gm chickpea along with protein (18-22%), carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorus, iron) and vitamins (Ali &Mishra, 2006). Common uses in United States are in Soups, vegetables combinations, or as a component of fresh salads in restaurant salad bars. Chickpea is valued for its nutritive seeds with high protein content, 25.3-28.9%, after dehulling (Haulse, 1991). It is already a traditional component of the Nepalese diet but is becoming increasingly scarce.

According to the year book (2011/2012) area, production and productivity of chickpea was 9154.23 ha, 8191.6 kg and 895 kg/ha, respectively which are more than area, production and productivity of 2010/2011 which was 9124.45 ha, 8130.45kg and 891kg/ha, respectively.

Chickpea (*Cicer arietinum* L.) is the most important leguminous crop for vegetarian diets in Nepal, as rich sources of proteins and essential amino acids. It is remunerative and has high water use efficiency. It fixes atmospheric nitrogen, improves

soil fertility and maintains the sustainability of the cropping system (Pandey, Neupane, Stevenson, Bouari, Rao, & Kishor, 2004).

It is mostly consumed as whole seed (boiled, roasted, parched, fried, steamed, sprouted etc.), dal (decorticated split cotyledons boiled and mashed to make a soup) or as dal flour (*besan*). Plucking of tender leaves and twigs and using as green vegetable is a traditional practice among some communities in the terai. Seed is a good source of protein (18-22%), carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorus, iron) and vitamins. Its straw has also good forage value (Shrestha, Neupane, & Adhikari, 2011).

2.2 Importance of pulse beetle (*Callosobruchus chinensis* L.)

Major insect pests that cause infestation on stored grain are given in Appendix 1. (Shrivastava, 1996).Pulse beetle (*Callosobruchus chinensis* L.) are the major storage pest of grain legume beside few other insects and cause 15 to 20% damage of total pulse grains production throughout the world (Kumar et al., 2003). Pulse beetle attack mainly in storage condition but inoculation may start from the field condition during the maturity of the crops and are carried into the store. They are detected when more than 40-50% grains are damaged because damage is noticed only after the emergence of adults (Sinha & Srivastava, 2005).

Infestation commonly begins in the field, where eggs are laid on maturing pods. As the pods dry, the pest's ability to infest them decreases. Thus dry seeds stored in their pods are quite resistant to attack, whereas the threshed seeds are susceptible to attack throughout storage.

The losses by insects like bruchids and weevils do not include only the direct consumption of the seeds and food products, but also the other reasons such as the amassing up of insect cadavers, exuviae and webbings, which makes the food and seeds unfit for human consumption (Rajashekar, Bakthawatsalam, & Shivanandappa, 2012).

Southgate (1979) stated that pulses grown by man had been infested by bruchids since the dawn of agriculture. The larval stage caused only severe damage rendering the seeds unfit for planting and human consumption. In the laboratory study, Rahman (1991) found that the initial presence of 4 larvae or eggs or one pair of *Callosobruchus spp.* adult could completely damage 10 g of the pulse grain within 2-4 month depending on the type of the pulses, stage of maturity and species of the beetle.

Gujar & Yadav (1978), recorded 55-60% loss by seed weight and 45-66% loss in protein content by the pulse beetle. Results revealed that 50.37-57.58% (Ali, Latif, & Ali, 2009) and 37.30-55.30% (Ali & Rahman, 2006). Grain content loss of mungbean seed was occurred by *C. chinensis* and *C. maculatus* respectively. The extent of damage of mungbean seed might be up to 100% during a period of one year storage (Chowdhury, 1961).

A laboratory experiment was carried out to assess *C. chinensis* infestation and the percent of average weight loss due to infestation in chickpea (*C. arietinum* cultivars Vijay, Vishal, desi type and kabuli type), arhar (*cajanus cajan* L. Millsp.), green gram (*Vigna radiate* L.), pea (*Pisum sativum* L.) and kidney bean (*Phaseolus vulgaris* L.) seeds. Kabuli type registered the highest number of *C. chinensis* adult eclosion, however, there was no adult eclosion observed in kidney bean. Green gram incurred highest weight loss due to infestation (Sarmah, Das, & Patgiri, 1996).

Most of the pest attack was reported in rainy and summer season and least attack was reported in spring and winter. This was also due to the fact that high moisture favors high pest population (Ali, Latif, & Ali, 2009).

Khalequzzamanm & Rumu (2009) reported that *Callosobruchus species* are major pests of stored grains and grain products in the tropics and Over 90% of the insect damage to cowpea seeds is caused by *Callosobruchus maculatus* (F.). Infestation may reach 100% within 3–5 months of storage and Control of *C. maculatus* relies heavily on the use of synthetic insecticides and fumigants, which has led to problems such as disturbances of the environment, increasing costs of application, pest resurgence, pest resistance to pesticides and lethal effects on non-target organisms in addition to direct toxicity to users.

Chickpea seeds in developing countries suffer heavy qualitative and quantitative losses from attack of the pulse beetle (*Callosobruchus chinensis* L.) (Alam, 1971; Abrol, 1999). Almost 8.5 % of total annual production is lost during postharvest handling and storage (Agrawal, Lal, & Gupta, 1988).

In general annual loss due insect pest has been estimated to be 15-30% (KC, 1992; Neupane, 1995) and in times of epidemics the figure may exceed. In storage condition storage pests consumes 5- 7% of grain and the damage is up to 30-50% (Agrios, 1988: Caswell, 1981).

In Nepal, losses cause by stored grain pest ranges from 10-30%. Insect pests, which cause damage to stored grains, are beetles (Coleoptera) and moths (Lepidoptera). Of these

beetles are far more diversified and are highly destructive in comparison to moths (Upadhyaya, & Ahmad, 2011).

In spite of the use of all available means of plant protection, about 1/3 of the yearly harvest of the world is destroyed by the pests (Dubey, Shrivastava, & Kumar, 2008). Losses at times are so severe so as to lead to famine particularly in humid tropical climates, where at least half of the food supplies may be lost between harvest and consumption (Dubey, Suresh, & Singh, 2007).

2.3 Biology of chickpea pulse beetle (*Callosobruchus chinensis* L.)

Taxonomic classification of Pulse Beetle (*Callosobruchus* chinensis L.)

Domain: Eukaryota
Kingdom: Metazoa
Phylum: Arthropoda
Subphylum: Uniramia
Class: Insecta
Order: Coleoptera
Family: Bruchidae
Genus: *Callosobruchus*
Species: *chinensis* L.

Adult *Callosobruchus* beetles do not feed on stored produce, and are very short-lived, usually no more than 12 days under optimum conditions. During this time the females lay many eggs (*C. chinensis* up to 70 days), although oviposition may be reduced in the presence of previously infested seeds (Chavan, Singh, & Singh, 1997).

Pulse beetle infestation is high in storage condition, however infestation was started from the field condition, where female deposited eggs on mature green pods. After hatching, larvae bore through pod and finally enter into grain. Such infested seed when place in storage condition, serves as source for further infestation. The larvae bore seed, feed it internally, complete several larval stages and also pupate inside the seed. After pupation completes, the adult emerge out leaving the hole form where they exit, and deposit eggs on another seed and start new cycle of development. It requires three to four weeks to complete a complete cycle and there may be 10 to 14 generation per year. Under favorable physical and climatic condition they can destroy all the seed of the storage.

Adult copulate within one hour of their emergence from the seed. Mating lasts for about 5-8 minutes at 70% relative humidity and 30°C temperature (Raina, 1970). Single mating is not sufficient and they mate several times in their life (Khare, 1994). But K.C. and Shrestha (1973) reported that the female starts laying eggs one day after mating. As soon as the egg is laid, females cover it for about 30 second, during that time the secretion fastening the egg to the dry seed (Khare, 1994). He further reported that the eggs are laid singly but several of them can be seen on one grain. He also stated that female laid an average of 78 eggs ranging from 63-90 over a period of 8 days. But K.C. and Shrestha (1993) reported that a single female could lay almost 150-200 eggs. Freshly laid eggs are oval, translucent, smooth and shining but become pale yellow or grey white along with maturity (Khare, 1994).

Larvae hatch from eggs on either seeds or pods use their mouthparts to bore through the bottom of the chorion. The eggs are glued on the pod or seed surface. After four to six days the larvae hatch and bore into the seeds directly into the eggshell. Within the seeds, larva undergoes four instars, the longest of which is the fourth (Singh et al., 1992 cited by Ghimire, 2001). According to K.C. and Shrestha (1993) egg hatches within about 7-14 days during April/May and 4-6 days during September/October, while in November/December it takes 8-16 days. The entire development of larva and pupa takes place inside a single seed and the emergence of adult takes place 21-23 days under optimal condition (32^{0}C) and fecundity is about 100 eggs, with the rage of 40-120 eggs per female (Hill, 1990). The life span of adult is 5-10 days.

Activity of all the larval instars prior to their emergence as adult was confined to a single seed feeding upon the fleshy cotyledons substance leaving behind the excreta, larval castings and body fragments under the coverage of seed coat (Manohar & Yadav, 1990). Larval and pupal period lasts for about 18-20 days and complete development form egg to adult takes in an average of 22-23 days.

Parajuli, Neupane, & Thapa, (1989) reported that *C. chinensis* had 13 overlapping generations in a year when reared on lentil grain and the insect completes its life cycles in 3 weeks during march-October but during winter, the life cycle of the beetle was prolonged and requires 4 weeks to complete a generation during November-December; whereas during peak winter season it took more than 13 weeks. However, K.C. and Shrestha (1993) reported that the beetle could complete 7-8 generation in a year in a Khatmandu valley. There are several generation in a year and do not hibernate (Khare, 1994).

The adult is 3-4mm long, egg shaped brownish in color with black margins. They have slightly serrate antennae, brown legs and two typical spines o the hind femur. The elytra do not fully cover the abdomen and in non-flying female, the pygidium is black with a median line of white hairs (Hill, 1990).

2.4 Male and female identification

The distinctive character of males and females has been well documented by Raina (1970), and Rajak and Pundey (1965).Antennas of male are pectinate type with elongated and oblong apical segment and curved towards each other. Pectinaton in antenna become prominent from the 4th to the apical segment. Antenna of female is straight but serrate type with prominent serration in 5th to the apical segment. The apical segment is somewhat bluntly rounded or ovate in shape. Male and female pulse beetles easily be distinguished from one another by general appearance. The most distinguishing characteristics is the sex specific coloration of the post abdominal plate that's called 'Pygidium'. In the female, the plate is enlarged and is darkly colored on both sides. In the male, the plate is smaller and lacks stripe. In some strains, females are larger in size than males. Also, females are black in coloration and males are brown.

2.5 Origin and distribution of pulse beetle (*Callosobruchus chinensis* L.)

C. chinensis L. was first reported and described from China in 1958 (Alam, 1971). Though Southgate (1979) has mentioned that the species of bruchidae have their origin in Afro Asian region. According to him, the species of bruchidae in every continent except Antarctica. Through the agency of man bruchids have their cosmopolitan distribution. Most of the species lived in the tropical regions of Asia, Africa, Central and South America. *C. chinensis* L. is of Asian origin, where it is still the dominant species (Dennis& Hill, 1990). He mentioned that *C. maculatus* thought to be African. However, both the species are now widely distributed throughout the warmer parts of the world. Other species of *Callosobruchus* recorded as pest include *C. analis* (Fab.) in parts of Asia on *Vigna species*, *C. phaseoli* (Gyllenhal) in Africa, parts of Asia and South America on Vigna and Dolichos lablab, *C. rghodesinus* in Africa on cowpea *C. sibinnotastus* (pin) in East Africa on *V. subterranea* and *C. theobromae* (Linn) in India on field crops of pigeon pea. Rahman & Sarpa, (1942) recovered that the bruchidae contains more than 100 injurious species distributed over different part of the world. Among them, 11 injurious species were recorded.

2.6 Pest management practices in storage

For the protection of the stored stock, people have been using chemicals such as, phenyl tablets, phosphine tablets, botanicals including Neem, Tobacco and Eucalyptus leaves and seeds and inert material like sand, salt and ash (Chomchalow, 2003**).**

Miah, Elias, Torofder, Islam, Sardar, & Karim, (1993) reported the effects of several Bangladeshi plant materials against *C. chinensis* on chickpea seeds. Nishinda (*Vitex engundo*) leaf powder was the most effective in reducing numbers of eggs laid, adult emergence and seed weight loss.

Mahdi & Rahman, (2008) tested powdered spices (flowers of clove, rhizome of ginger and turmeric, fruits of black and chilli pepper and bulb of garlic), Malathion (1.5%) and powdered stem of the tree *Combrerum imberbe* mixed against *C. maculatus*. Reduction in oviposition and seed weight loss were recorded 10 and 70 days post-treatment respectively. Cloves and black pepper gave results, which were not significantly different from those produced by Malathion.

The biological activity of camphor, a major component of essential oil of the basil shrub, *Ocimum kilimandscharicum*, against the beetles, *Sitophilus granarius*, *S. zeamais*, *Tribolium castaneum* and *Prostephanus truncatus*, was investigated in the laboratory using contact toxicity, grain treatment and repellency assays. Camphor applied either topically, impregnated on filter papers or whole wheat and maize grains was highly toxic to all the four species. Beetle mortality was dosage-dependent with the highest doses of 100 mg/ filter paper and 100 mug/insect evoking over 93% and 100% mortalities, respectively, in *S. granarius*, *S. zeamais* and *P. truncatus* after 24 h exposure. Similar doses induced 70% and 100% mortality in *T. castaneum*. Camphor impregnated on the grain surface was more effective than on filter paper. There was, however, highly significant reduction in toxicity in grain after only 24 h following treatment. Development of eggs and immature stages within grain kernels, as well as progeny emergence, was completely inhibited in camphor-treated grain. Camphor was also highly repellent to the beetles with overall repellency in the range of 80-100%. The potential use of suitable products derived from *O. kilimandscharicum* as supplementary or alternative grain protectants against insect damage in traditional grain storage in developing countries is discussed (Obeng-Ofori et al., 1998).

2.6.1 Chemical method of control

In order to keep these stored grain products free from pest attack, various synthetic chemicals have been used. Synthetic pesticides are currently the method of choice to protect stored grain from insect damage. But, continuous or heavy uses of synthetic pesticides has created serious problems arising from factors such as direct toxicity to parasites, predators, pollinators, fish and man. It also develops pesticides resistance (Zettler, 1991; Mahmud, Khan, Husain, Alam, & Afrad, 2002), susceptibility of crop plant to insect pests and increased environmental and social cost (Pimentel, 1980)

The people generally prefer to use chemicals like Naphthalene / phenyl tablets as these are cheap and ready to use. Moreover, these are very effective especially in wheat *Triticum aestivum* L. storage to control pest population (Latif, Rahman, Alam, 2004).

At present, pest control measures in storage rely on the use of synthetic insecticides and fumigants, which is the quickest and surest method of pest control but it is also not advised to mix the insecticides with food grains. Their indiscriminate use in the storage, however, has led to a number of problems including insect resistance, toxic residues in food grains (Fishwick, 1988), environmental pollution (WMO, 1995) and increasing costs of application. In view of these problems together with the upcoming WTO regulations, there is a need to restrict their use globally and implement safe alternatives of conventional insecticides and fumigants to protect stored grains from insect infestations (Shaheen, & Khaliq, 2005).

In Nepal farmers use BHC, Aluminium phosphide and Malathion as grain protectant chemicals against storage pests (Thapa, 1994). Parajulee et al. (1989) reported that Malathion both at 50 and 100 ppm prevented oviposition of *C. chinensis* on lentil grain and drastically reduced its adult emergence.

The chemical method of stored grain pest control is effective in controlling weevils. This method, however leads to presence of undesirable residue, making unfit for consumption. The most commonly used chemical pesticides to combat the storage pest are fumigating agents Malathion, Nuvan, Aluminium phosphide (celphos), which are toxic and release toxic gases when exposed to the environment (Joshi, Karmacharya, & Khadge, 1991). So great care must be taken while using these chemical pesticides as some of the dusts cause great level of intoxicant effects.

The use of synthetic chemicals to control post-harvest bio deterioration has been restricted due to their carcinogenicity, teratogenecity, high and acute residual toxicity,

hormonal imbalance, long degradation period, environmental pollution and their adverse effects on food and side effects on humans (Brent & Hollomon, 1998; Dubey, Rajesh, Jaya., & Dubey, 2007; Kumar, Mishra, Dubey, & Tripathi, 2007).

The use of synthetic chemicals as antimicrobials for the management of plant pathogens have undoubtedly increased crop protection but with some deterioration of environmental quality and human health (Cutler & Cutler, 1999). Their uninterrupted and indiscriminate use has not only led to the development of resistant strains but accumulation of toxic residues on food grains used for human consumption has led to the health problems (Sharma & Meshram, 2006)

Another method is the use of synthetic fumigants, which has also led to increased cost of application, pestresistance, lethal effects on non-target organisms and toxicity to users (Okonkwo & Okoye, 1996).

2.6.2 Use of essential oils in storage pest management

In recent years, the use of various bio-pesticides, edible and non-edible oils and plant extracts have gained much importance due to their high bio-efficacy against a wide range of stored pests with no residual toxicity to the environment as compared to chemical pesticides (Kumari & Singh 1998).

Rajasekaran and Kumaraswami (1985) evaluated the effectiveness of extracts of Karanja (*P. glabra*) and neem (*A. indica*) for the control of *Sitophilus oryzae* and *C. chinensis* on sorghum and green gram (*V. radiata*) grain. Coating sorghum grain with karjana extract with 0.4% vol/vol or with neem extract at 1.0% wt/wt. gave complete protection from *S. oryzae*. Coating green gram grain with the 2 extracts at 0.8% wt/wt respectively, gave significant protection from *C. chinensis*.

They also possess insecticidal as well as repellent properties with little or no mammalian toxicity and no effect on germination and cooking quality of the treated seeds (Vishwamithra, Vijayalakshmi, & Loka Reddy, 2014).

Two major constituents of the essential oil of garlic, *Allium sativum*, methyl allyl disulfide and diallyl trisulfide were to be potent toxicant and fumigants against *Sitophilus zeamais* and *Tribolium castaneum* (Huang, Chen, & Ho, 2000). The essential oil vapours distilled from anise, cumin, eucalyptus, oregano, and rosemary were also reported as fumigants and caused 100% mortality of the eggs of *Tribolium confusum* and *Ephestia kuehniella* (Tunç, Berger, Erler, & Dagli, 2000).

Plant essential oils and their constituents in relation to contact and fumigant insecticidal actions have been well demonstrated against stored product pests. Especially their main compounds monoterpenoids, offer promising alternatives to classical fumigants (Papachristos & Stamopoulos, 2003) and also have some effects on biological parameters such as growth rate, life span and reproduction (Pascual-Villalobos, 1996).

Essential oil and their constituents have been shown to be a potent source of botanical pesticide. The toxicity of a large number of essential oils and their constituents has been evaluated against a number of bruchid pests (Kéita, Vincent, Schmit, Arnason, & Belanger; 2001, Tripathi, Prajapati, Verma, Bhal, Bansal, Khanuja, & Kumar, 2002).

Rahman, & Talukder (2004) conducted experiments to study the bio-efficacies of different plant/weed derivatives that affect the development of the pulse beetles, *C. maculatus* F. (Coleoptera: Bruchidae) feed on black gram, *V. mungo*, seeds. Plant extracts, powder, ash and oil from nishinda (*Vitex nigundo* L.), eucalyptus (*Eucalyptus globules* Labill), bankalmi (*Ipomoea sepiaria* K.), neem (*Azadirachta indica*), safflower (*Carthamus tinctorius* L.), sesame (*Sesamum indicum* L.) and babla (*Acacia arabica* L.) were evaluated for their oviposition inhibition, surface protectant, residual toxicity and direct toxicity effects on *C. maculatus*. The results showed that plant oils were effective in checking insect infestation.

Botanical insecticide composed of essential oils may be a sound alternative to the more persistent synthetic pesticides for managing the major pests of stored product insects (Sahaf & Moharramipour, 2008).

Pirimiphos-methyl (Actellic), an organophosphate, registered in the USA for treating stored corn and sorghum has lower mammalian toxicity showed to be effective on wheat against several stored-product insects (Huang, & Subramanyam, 2007).

According to Khaire, Kachare, & Mote (1992), Pre-storage seed treatment of mungbean (*Vigna radiate*)cv. PS-16 with oils of neem (*Azadirachta indica*), karanja (*Pongamia pinnata*), (Indian) mustard, groundnut and castor (*Ricinus communis*) at 2.5, 5.0 and 10.0 ml/kg seed was tested as a surface protectant against *Callosobruchus chinensis*. Seeds treated with thiram 75 WP (2.5 g/kg) were used as a control and the effect on seed viability was tested. Karanja oil, mustard oil and castor oil (10 ml/kg seed) were found effective in halting the embryonic development in *C. chinensis* and protected the seed over a period of 21 months after treatment followed by Neem oil which gave protection for up to 12 months. A significant reduction in germination was noticed among

the treatments with neem oil and groundnut oil at 10 ml/kg where seed viability was maintained for up to 6 months, while at the lower dosage (2.5 and 5 ml/kg seed) viability was maintained for up to 18-21 months, resp. Karanja oil, castor oil and mustard oil even at 10 ml/kg seed did not show any adverse effects on seed viability for up to 18 and 21 months, resp. There was a progressive increase in moisture content of the seeds with different treatments during storage which was on par with the control.

2.6.2.1 Citronella (*Cymbopogon nardus*rendle) oil

Citronella oil is one of the essential oils obtained by stem distillation of partially wilted leaves of from the leaves and stems of different species of *Cymbopogon* (lemongrass). The oil is used extensively as a source of perfumery chemicals such as citronellol and geraniol. These chemicals find extensive use in soap, candles and incense, perfumery, cosmetic and flavouring industries throughout the world (Lawless, 1995). The composition of chemical constituents are vary with different species of *Cymbopogon* and composition in two species C. nardus Rdndle and *C. winterianus* Jowitt are geraniol (18-20%), limonene (9-11%), methyl isoeugenol (7-11%), citronellol (6-8%), and citronellal (5-15%) and (32-45%), geraniol (11-13%), geranyl acetate (3-8%), limonene (1-4%), respectively.

Nayanathara, & Ratnasekera, (2010) reported that repellent activity of Cinnamon (*Cinnamomam verum* Presl.) bark oil vapour and Citronella (*Cymbopogon nardus* L.) oil vapour was evaluated against *Callosobruchus chinensis* L in bulk stored green gram. Both oils were used at 5ml and 10ml/5kg of seeds in 3L plastic baskets. Oviposition and damaged seeds were observed up to two months. At the end of the storage period, the effect of the treatments on flavour, consumer acceptability and seed germination was evaluated. Both oils inhibited population growth of *C. chinensis* as compared to untreated seeds. Both oil vapours at 5 and 10ml/5kg protected green grams from infestation by *C. chinensis* for 2 months. Amongst the two Cinnamon bark oil vapor was more effective than Citronella oil vapour in both concentrations used. No harmful effect was observed on the germination of oil vapour treated seeds.

2.6.2.2 Mentha (*Mentha arvensis*) oil

This oil is obtained by steam distillation of the aerial part of *Mentha arvensis* L. it is commonly called Mentha. Mentha is an aromatic plant herb growing at sub-tropical

climatic zone. Leaves are obtusely or acutely serrated. Flowers are small, hairy and pinkish white.

Mentha arvensis (field mint) wild mint or corn mint) is a species of mint with a circumboreal distribution. It is native to the temperate regions of Europe and western and central Asia, east to the Himalaya and eastern Siberia, and North America. Chemical substances that can be extracted from wild mint include menthol, menthone, isomenthone, neomenthol, limonene, methyl acetate, piperitone, beta-caryophyllene, alpha-pinene, beta-pinene, tannins and flavonoids (Maria et al., 2015).

2.6.2.3 Clove (*Syzygium aromaticum*) oil

Cloves are the aromatic flower buds of a tree in the family Myrtaceae, *Syzygium aromaticum*. They are native to the Maluku Islands in Indonesia, and are commonly used as a spice. Cloves are commercially harvested primarily in Indonesia, India, Madagascar, Zanzibar, Pakistan, Sri Lanka and Tanzania.

Eugenol comprises 72-90% of the essential oil extracted from cloves, and is the compound most responsible for clove aroma (Kamatou, 2012). Other important essential oil constituents of clove oil include acetyl eugenol, beta-caryophyllene and vanillin, crategolic acid, tannins such as bicornin (Bao, Eerdunbayaer, Eizo, Keinosuke Hideyuki, & Tsutomu, 2012), gallotannic acid, methyl salicylate (painkiller), the flavonoids eugenin, kaempferol, rhamnetin, and eugenitin, triterpenoids such as oleanolic acid, stigmasterol, and campesterol, and several sesquiterpenes (Bhowmik, Kumar, Yadav, Srivastava, Paswan, & Dutta, 2012). Eugenol is toxic in relatively small quantities; with a dose of 5 - 10 ml severely affecting a 2 year old child (Hartnoll, 1993).

Both pre-and post-oviposition application of the essential oils significantly suppressed oviposition and/or adult emergence. In the pre-oviposition application, treatment of bambaranut seeds with clove, WABP and ginger oils at the rate of 1 mg/5 g seed reduced the mean number of eggs laid by *C. maculatus* by 70.7, 98.7 and 86.2%, respectively, relative to the number of eggs laid in untreated seeds. Post-oviposition treatments were, however, more effective on average, than pre-oviposition treatments in reducing the proportion of *C. maculatus* adults that emerged. In the post-oviposition application, no adult *C. maculatus* emerged in Bambara nut seeds treated with clove oil at the rate of 0.5 or 1 mg/5 g seed. According to Huang and Subramanyam (2005), the clove

oil itself is dominated by eugenol (70 to 85%), eugenol acetate (15%) and β-caryophyllene (5 to 12%), which together makes up 99% of the oil.

2.6.2.4 Eucalyptus (*Eucalyptus spp*.) oil

Eucalyptus oil is the generic name for distilled oil from the leaf of Eucalyptus, a genus of the plant family Myrtaceae native to Australia and cultivated worldwide. Eucalyptus oil is obtained by steam distillation of fresh or semi dry leaf materials of Eucalyptus sp. It is commonly called Masala in Nepali. Eucalyptus oil has a history of wide application, as a pharmaceutical, antiseptic, repellent, flavouring, fragrance and industrial uses. The leaves of selected Eucalyptus species are steam distilled to extract eucalyptus oil. (Active compound found "eucalyptol", another name for cineole.

Cineole-based eucalyptus oil is used as an insect repellent and bio pesticide. In the U.S., eucalyptus oil was first registered in 1948 as an insecticide and miticide (Dhumal, & Waghmare, 2015).

Eucalyptus oil which could not prevent the egg laying of the beetle recorded more adult emergence and subsequent high infestation and weight loss. The reports are in agreement with the findings of Patil, Nawale, & Mote(1994).The monocyclic monoterpene 1, 8-Cineole (eucalyptol) is the major component of different species of Eucalyptus having fumigant action against *Tribolium castaneum* (Rajendran & Sriranjini, 2008).*Eucalyptus citriodora* is good applicant for use as repellents against *Tribolium castaneum* (Olivero-Verbel, Nerio, & Stashenko, 2010).The essential oil of *Eucalyptus Species* contains metabolic compounds such as terpenoids and phenolic compounds (Moore, Walls, Pala-Paul, Brophy, Willis, & Foley, 2004) and are toxic to stored product pests (Coleoptera) (Lee, Annis, Tumaalii, & Lee, 2004; Tapondjou, Adler, Bouda, &Fontem,2005) and agricultural pests (Lepidoptera) (Isman, 2000) has already been reported.

2.6.2.5 French basil *(Ocimum basilicum*) oil

Frech basil oil isobtained by steam distillation of semi-wilted flowering tops of Ocimum basilicum L. and commonly called basil. Basil is an aromatic erect, annual herb, Leaves are petioled, ovate and toothed. Flowers are purple white in recemes. Whose major constituent is linalool, has been employed successfully against some insects (Weaver, Dunkel, Ntezurubanza, Jackson, & Jackson, 1991). Native to India, Afghanistan, and Pakistan, basil is a strongly aromatic annual growing to about twenty to thirty inches in height. French basilus (*Ocimum basilicum* L.) contains lower amounts of Phenols and

Eugenol. A study of the essential oil showed antifungal and insect-repelling properties. A similar study reported in 2009 has confirmed that extracts from the plant are very toxic tomosquitoes. However, the plant is not toxic to rats. Little information is available about any potential toxicity in humans (Maurya, Sharma, Mohan, Batabyal, & Srivastava, 2009).

Many species of the genus Ocimum oils, extracts, and their bioactive compounds have been reported to have insecticidal activities against various insect species (Kéita, Vincent, Schmit, Arnason, & Belanger, 2001).

2.6.2.6 Neem (*Azadirachta indica*) oil

Azadirachtin obtained from neem tree [*Azadirachta indica.* A. Juss (family: Meliaceae)] is one of the most important biopesticide currently in use. The broad spectrum activity of azadirachtin at very low concentration coupled with the unique mode of action and non-toxicity to mammals make azadirachtin an ideal candidate for insecticidal use.

Neem oil is a vegetable oil pressed from the fruits and seeds of the neem (*Azadirachta indica*), an evergreen tree which is endemic to the Indian subcontinent and has been introduced to many other areas in the tropics. It is the most important of the commercially available products of neem for organic farming and medicines.

Azadirachtin is the most well-known and studied triterpenoid in neem oil. The azadirachtin content of neem oil varies from 300 ppm to over 2500 ppm depending on the extraction technology and quality of the neem seeds crushed. Nimbin is another triterpenoid which has been credited with some of neem oil's properties as an antiseptic, antifungal, antipyretic and antihistamine. Neem oil also contains several sterols, including (campesterol, beta-sitosterol, stigmasterol (Karus, 1993).

In Bangladesh, Das (1987) investigated the effect of various concentrations of neem (*A. indica*) oil on adult mortality and oviposition of *C. chinensis* in the laboratory at 32.50C and 83-85% R.H. Ten pairs of newly emerged male and female adults of *C. chinensis* were introduced into pots containing 50g chickpea (*Cicer arietinum*) seed treated at 4, 6, 8 and 10 ml/kg seeds. Adult mortality was significantly greater at all concentrations of treated seeds compared with the untreated seeds. The highest mortality of 100% was observed at 8 and 10ml/kg seeds. The total number of eggs laid on the seeds treated at 6, 8 and 10ml/kg seed significantly lower than the untreated seeds or those treated at 4ml/kg seed. It is concluded that 8ml of oil/kg seed is the most economic concentration to control *C. chinensis* infestation on chickpea seeds.

Mohapatra, Kar, & Giri, (2015) tested vegetable oils in the laboratory at 5 to 10 ml/kg seeds against adults of *C. chinensis* infesting pigeon peas (*Cajanus cajan*); oils of neem and Karanja (*Pongamia glabra*) at higher concentration were the most toxic.

2.6.2.7 Bojho (*Acoros calamus*) oil

Risha, El-Nahal, & Schmidt, (1990) studied the toxicity of *Acorus calamus* rhizome oil vapors against the immature stages of *Sitophilus granarius, Sitophilus oryzae, Tribolium confusum* and *Callosobruchus chinensis*. It was observed that the eggs of *C. chinensis* were the most susceptible; the eggs of *S. granarius* were slightly more susceptible than those of *S. oryzae*, while those of *T. confusum* were not affected, at all. In all cases, younger embryonic stages were more susceptible than the later stages. Larvae and pupae, however, did not show any appreciable susceptibility to the vapors.

Kumari, Kumari, & Verma, (1999) used*Acorus calamus* oil and B-asarone, to coat grains of maize, and investigated the effects on *Prostephanus truncatus*, in the laboratory. Maize was also treated with the powdered rhizomes of *Acorus calamus*. The oil treatment reduced the feeding by 50%, within 21 days. A decrease in the feeding was observed in maize, treated with B-asarone, after 21-42 days, at 30 °C but not at 25 °C. The admixture of rhizome powder also reduced the feedings up to 83%.

2.7 Fumigant toxicity of essential oils against storage pest

Many studies have demonstrated differential susceptibility of stored product beetle species to the essential oils. *C. chinensis* species was more susceptible to essential oils or their components than those of other insect species (Subramanyam, & Hagsturm, 1994; Lee, Annis, Tumaalii, & Lee, 2004).

Toxicity of five essential oils (EOs), viz. cardamom, cinnamon, clove, eucalyptus and neem oils were investigated against the cowpea weevil, *Callosobruchus maculatus* (Fab.) adults, through contact and fumigation bioassay. In the contact bioassay eucalyptus oil was found to be the most effective in inducing mortality both after 24 and 48 h of treatments. The toxicity of the oils followed in the order: eucalyptus > clove > cinnamon > cardamom > neem. In the fumigation bioassay, however, a reverse result was obtained with eucalyptus oil where it shows the last position for 24 h and fourth position for 48 h after treatments. The efficacy in respect of the toxicity followed in the order: clove > cinnamon > cardamom > neem > eucalyptus after 24 h after treatment, and clove > cinnamon >

cardamom > eucalyptus > neem after 48 h after treatments (Mahfuz & Khalequzzaman, 2007).

2.8 Selection of storage structure

Storage of grain in airtight containers has been widely promoted as a means of reducing post-harvest losses. However, the grain moisture content in such structure should not exceeds 13% that may leads to insect heating which can severely damage the grain quality (Ransom, 2000). Reducing the oxygen content in a storage structure can reduce the insect survival if it is reduced below 3% of air (Manandhar & Mainali, 2000). Using air tight condition can do this. An ideal structure means a structure or container, which can check the entry of harmful elements, prevent the exit of beneficial elements and still, facilitate to load, unload and fumigate when needed. Manandhar et al. (2000) mentioned that airtight storage of any agriculture commodity is known mainly for its simplicity and pest control without the use of toxic chemicals. However, grain moisture should be reduced as far as possible to use the airtight methods.

A total of seven containers viz. cloth bags, paper bags, jut bags laminated with thin(200 gauge) plastic film, sealed steel bins, aluminium foil pouches and polythere bags(700 gauge) were evaluated for cowpea storage treatment with respect to seed germination and seedling vigor. Among storage containers used, seed with seven percent moisture, stored in polythene bags (700 gauge) maintained significantly higher percent of germination (40.2%) even at the end of storage period of two years. However, it is interesting to note that cowpea stored in jute bags laminated with thin polythene film showed higher germination percent (50.6%) followed by aluminium foil pouches(48.5%) and polythene (200 gauge) (46.9%) up to the storage period of one year, there after it is gradually declined at the end of storage period of 2 years. This study showed that germination and seed vigor (root shoot length) decreased as storage period increased irrespective of storage containers. Seed of cowpea in polythene bags(700 gauge) maintained significantly higher viability up to 2 years and proved to be appropriate for storing cowpea seeds for a period of 2 years (Dod, Panchabhai, & Chauke, 2005).

Ali, Latif, & Ali, (2009) reported that tin containers and plastic bags proved to be best in storing the wheat grains as compared to the gunny bags and earthen pots. The reason of high infestation in jute or gunny bags is that these storage facilities support ventilation and also increase the moisture content of the grains which results in moulding,

webbing and insect infestation. In contrast, the plastic bins and metal containers do not allow any air to flow in and also maintain the moisture content, thus keep the insect infestation low.

Baloch, Grapher, & Ricco, (1994) reported that jute bags are the reason of high infestation of insects in the grains. This might be the main reason why the majority of local population prefers to use metallic bins and only a few use bags and earthen bins. The poor storage structure and technical knowhow are limiting factors in safe use of chemicals leading accidental acute poisoning chronic hazards (Tapondjou, Adler, Bouda, & Fontem, 2002).

2.9 Hazardous effects of chemical fumigants

Insecticidal chemicals are usually the methods of choice of insect control (Cogburn, Hung, & Webb, 1989). Since the 1960s residual grain protectanct, chiefly organophosporus, pyrethroids and carbamate insecticides have been employed on a world-wide basis in management programs for insect pest control in stored raw agriculture commodities (Arthur, 1996). For the protection of rice grains from the colossal loss inflicted by storage insects, the use of insecticides or fumigants now days being made routine treatments (Prakash & Rao, 1987; Singh, Thapa, & Pandey, 1992).

The wide spread use of synthetic insecticides poses a serious hazards to both man and wildlife because of adverse effects on environments (Makanjuola, 1989). The detrimental effects on the ecosystem are well demonstrated when beneficial insects, predators and parasites die, but often pests, themselves, survive because population has developed resistance to the chemical used (Makanjoula, 1989; Jayasankhar & Alexander Jesudasan, 2005).

Karki (2002) and Entomology division (2000) pointed out unnecessary and indiscriminate use of pesticides in the storage of agriculture commodities is one of the challenges, ahead for post-harvest management in Nepal. The harmful effects of such chemicals are completely lacking where they are neither documented nor properly addressed with alternative control measures. Due to higher dose and repeated frequency of application of pesticides every year, one million people suffer from pesticide poisoning.

Synthetic pesticides are the major tools for crop protection in developed countries. However, considerable problems may arise from the continued application of these insecticides, including genetic resistance of insect species, toxic residues in the grains,

handling hazards, health hazards to operative and pest resurgence (Chiu, 1989; Rembold, 1989; Schoonhoven, 1982; Sharaby, 1988; Shaaya, Kostjukovski, Eilberg, &Sukprakaan, 1997).

These problems led to rapidly rising application and marketing costs. Continuous and heavy uses of synthetic insecticides results indirect toxicity to non- target organisms such as beneficial parasites, predators and others. Certain chemicals may also concentrated in food chains. Therefore, it may be worthwhile to seek insecticide supplements of natural origin (Owusu 2001, Talukder & Miyata, 2002).

2.10 Pest resistance to chemical pesticides

Control of these pests is primarily dependent upon repeated application of synthetic insecticides which results in pest resistance (Hasan & Reichmuth, 2004). Resistance to one or more insecticides has been reported in at least 500 species of insect and mites (Georghiou, 1990).

Champ (1985) reported that resistance to pesticides used to protect grain and other stored products is widespread and involves all groups of pesticides and most of the important pests. The development of cross and multiple resistant strains in many important insect species is a serious concern all over the world (Dyte & Halliday, 1985; Zettler & Curperus, 1990; Chaudhary, 1997).

Stored products insect pests were found to be resistant against different insecticides including the cyclodienes, bioresme thrin, carbamates, carbryl, chlolopyrifos, chlorpyrifos–methyl, Cyanophos, cyfluthrin, cyhalothrin, cypermethrin, DDT, deltamethrin, diazinon, dichlorovos, ethylene dibromide, fenitrothion, lindane, malathion, methyl bromide, organophosphate, permethrin, phosphine, phoxim, promecarb, propoxur, pyrethrins, temephos and etrachlorvinphos (DARP, 2003). The resistance of certain store product pest to widely used food industry pesticides has reached the highest levels ever recorded in the USA (Fehrenbach, 1991). In another example, Malathion resistance in stored product insect-pests was reported from all over the world and currently, there 122 insect-pest species, which are found as resistant to this insecticides (DARP, 2003).

Fumigation is still one of the most effective methods for the prevention of stored product losses form insect-pests, but stored product insects were showing a slow upsurge in fumigation resistance (Donahaye, 2000). Widespread resistance to phosphine has emerged in several species of stored-product insects in many countries, which in some

instances may have caused control failures (Chaudhary, 1997). Benhalima, Chaudhary, Mills, & Price, (2004) investigated the phosphine resistance status of insect pests in Morocco and found that, with the exception of one population of *S.oryzae*, all samples tested contained phosphine resistant individuals.

The indiscriminate use of pesticides has made the development of insecticidal resistance in many of the strains of insect. The development of resistance to chemicals in stored grain pest has been slow, somehow (Khare, 1994). Global survey set up by Food and Agriculture Organization (FAO) revealed that at least 13 species of beetles, 5 moths and 2 mites have have developed resistance to insecticide attacking stored grain and grain products(Khare, 1994). The development of insecticides resistance is a constant concern in post-harvest ecosystem (Arthur, 1996). Malathion resistance has been extensively documented for many important stored-product insect pests throughout the world (Subramanyam & Hagstru, 1995).

The most commonly used chemical pesticide to combat the storage pest is a fumigating agent Malathion, Nuvan, Aluminium phosphide (celphos), which are toxic and release deadly gases when expose to the environment (Joshi et al., 1991). Beside, causing pest resistace, pesticides also kill beneficial organism and non-target organism (Dudani, 1995). In recent years, organism tend to develop resistance to chemical pesticides has increasing, Gips, (1987) cited by Dahal, (1995) reported that resistance is most frequently seen in the Diptera species (156 species or 35%), followed by Lepidoptera (67 species or 15% of the total) and Coleoptera (66 species or 15% of the total).

Chemical method is most effective for shelled grain, which can impose a health hazard to those applying the insecticides but also to consumers. Fumigation with phosphine gas generated form aluminium or magnesium phosphide pellets is very effective in controlling insect pests but farmers often do not have airtight storage containers to enable a through fumigation (Bergvinson, 2000).

Many of the major insect pests of stored rice are now frequently found to be resistant to the commonly used insecticides (COPR, 1976). Study of rural wheat grain storage in Ludhiana, district Punjab reckoned the loss in Malathion treated grain as 0.5 percent and in untreated varying from 1.1 to 3.1 percent different storage practice (Khare, 1994). These situation further demands of eco-friendly management of insect pests and it can be obtained by the use of resistant varieties, other practical method of sanitation and biological measures (Dahal, 1995).

Thus, the use of botanical pesticides which are indigenous, effective and with low mammalian toxicity favors the eco-friendly and sustainable storage pest management by providing safe, environment-friendly and cheap source of preventive measures for stored product pests (Parugrug & Roxas, 2008).

Methyl bromide and phosphine fumigants have been used for decades to control stored pests (Islam, Hasan, Xiong, Zhang, & Lei, 2009) and belong to the most effective treatments to protect stored food, feedstuffs, and other agricultural commodities. Growers are moving away from using methyl bromide as post-harvest fumigant because of its ozone-depleting nature (Zhang & Van Epenhuijsen, 2004) and phosphine, due to repeated use as it disrupts biological system leading to the development of pest resistance (Ignatowicz, 1999; Zeng, 1999).

3 MATERIALS AND METHODS

This research comprises three types of studies. The first was farmers' field survey conducted in Surkhet condition and other two were laboratory experiments conducted in laboratory condition at Rampur Chitwan. One experiment was bioassay comprising chickpea grains, pulse beetles as pest and pesticidal materials. The next laboratory experiment was set to know the fumigation effects of the essential oils against pulse beetles.

3.1 Field survey

3.1.1 General description

A pretested semi-structured questionnaire was used to collect the information regarding general storage pest status, their situation on major cereal grain and management practices adopted by farmers. After survey, experimental trial was laid in Entomology laboratory of Agriculture and Forestry University, Chitwan. Survey was carried out in month of January, 2015 in Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district. Geographically Latikoili VDC was located on $88^0$55'N and $81^0$64'E, Ramghat located on $28^0$30'N and $81^0$43'E and Lekhgaun located on $28^0$48'N and $81^0$43'E. The general altitudes of those VDCs are 668 m, 489 m and 923 meter above the mean sea level respectively.

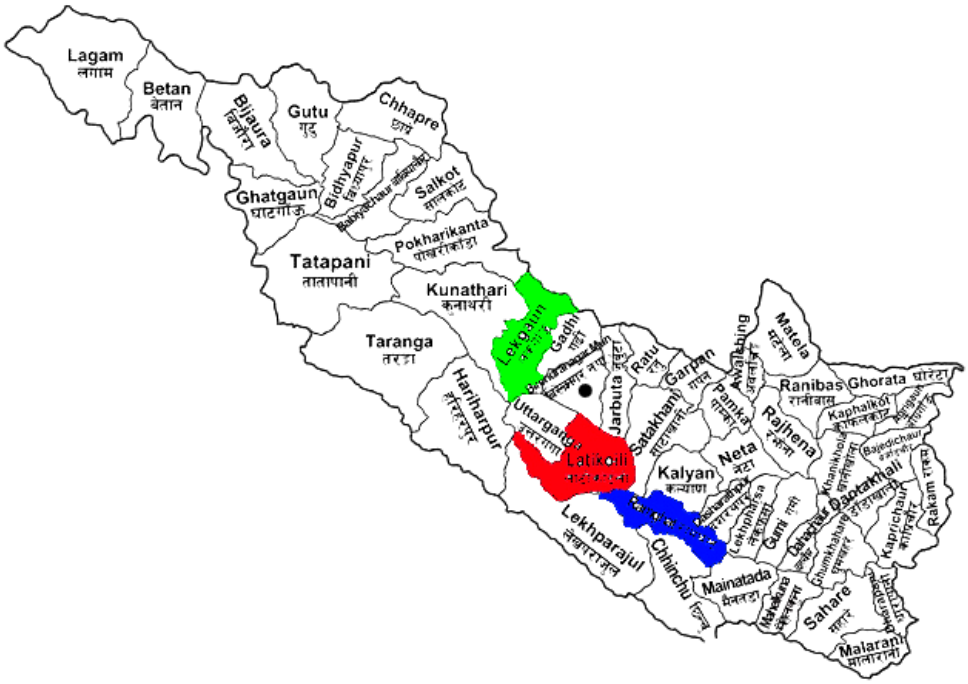

Figure 1. Ramghat, Latikoili and Lekhgaun VDCsof Surkhet district

3.1.2 Weather condition

The mean monthly temperature, rainfall and relative humidity during the survey period as recorded at Regional Metrological Office of Surkhet were used for the study. The average maximum and minimum temperature, humidity and rainfall during survey month of Surkhet district in 2014 (Appendix 19).

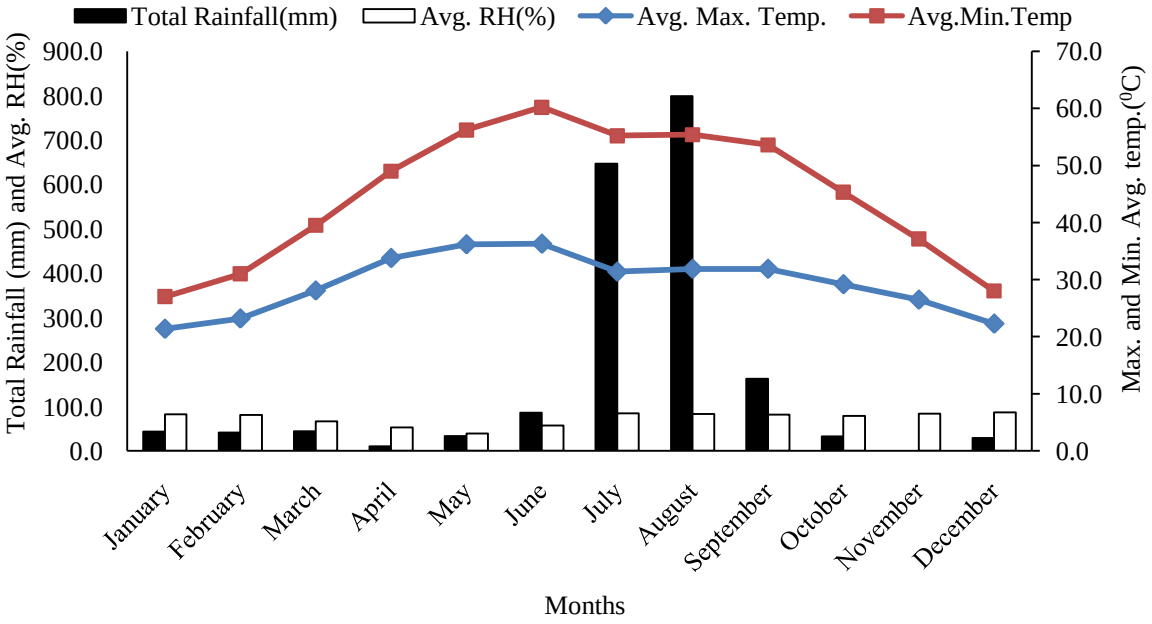

Figure 2. Climatological data during survey period in Surkhet in 2014

3.1.3 Questionnaire survey

Semi structured and pre-tested questionnaires were used and storage grain pest survey was conducted to gather information regarding storage pest situation, their status on major cereal grain and practices adopted by farmers. Storage grain pest survey was conducted on Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district comprising 15 farmers from each VDC. The farmers were purposively selected for the interview. Focal group discussion one at each VDC was also carried out to gather more information and for the confirmation of information gathered from individual framers.

3.2 Bioassay experiment

Bioassay experiment was carried out in laboratory condition using chickpea pulse beetle as subject, pesticidal materials as stimumuls and different effects of pesticidal materials on insect and chickpea seeds as responses. Bioassay experiment consists of nine treatments with three replication and laid out in Completely Randomized Design (CRD).

3.2.1 Materials

3.2.1.1 The seed

Chickpea seeds of Kosheli variety were purchasedform Regional Agriculture Research Station (RARS), Khajura, Nepalgunj were used in experiment.

3.2.1.2 The treatments

Seven different essential oils and Malathion dust were used as the treatment materials.Authentic Citronell oil, Mentha oil, Eucalyptus oil and French Basil oil were collected from Herbal Processing Center, Jadibuti-Bhaktpur. Commercial Neem oil and Bojho oil is a composition of blending of mint-41%, Eucalyptus oil-20%, Camphor-16%, Lemon grass oil- 3%, Winter grass oil-3%, Calamus oil-2%, Clove oil-2%, Xanthoxylum oil-2%, Ginger oil-1%) and Clove oil were used. Chemical Malathion dust (5% DP) was chemical check which was procured from local market.

3.2.1.3 Test insects

The test insect pulse beetle (*Callosobruchus chinensis* L.) was identified by using key given by Raina (1970) and multiplied in laboratory condition using standard rearing techniqueused for maintaining a pure culture. Male and female were identified by observing their antennae in microscope.

3.2.1.4 Major tools and equipments

Aluminium sheet bin, glass vials, binocular microscope, magnifying hand lens, electronic weighing balance, germination chamber, muslin cloth, forceps, scale, digital camera, Wile moisture meter, petri-plates, aspirators, Malathion, rubber bands, rope, maximum-minimum thermometer, dry bulb and wet bulb thermometer were the major tools and equipments used during experimentation.

3.2.2 Procedure used in insect rearing and bioassay

3.2.2.1 Maintenance and mass rearing of host insects

Adult insect specimen of *C.chinensis*L.werecollected from insectinfested stores. The specimens were identified as of morphological description by Khare, 1994 & Hill, 1990. Clean and undamaged Kosheli variety of chickpea sees were used for insect rearing. Maintenance and mass rearing of insect were performed at room temperature of

Entomology Laboratory of Agriculture and Forestry University (AFU). The culture was produced as pure culture and usedfor the inoculation into each experimental unit.

3.2.2.2 Study of pesticidal materials to control *C. chinensis* L.

3.2.2.2.1 Preparation of seed

The seeds were fumigated with Aluminium phosphide for 72 hours, thenafter washed thoroughly and sun dried. Initial moisture of seeds was recorded with the help ofWile Moisture Meter. The initial germination percentage of seeds was determined by blotting paper method. At the time of experimentation, the moisture content and germination percentage of chick pea seeds were recorded 12.8% and 93.5%, respectively.

3.2.2.2.2 Preparation of treatment materials

Readymade essential oils (Neem oil, Clove oil, Citronell oil, Mentha oil, Eucalyptus oil, Bojho oil, and French basil oil) were purchased from Herbal Processing Center, Jadibuti, Bhaktpur and Neem oil, Bojho oil and Clove oil, chemical viz. Malathion were purchased from nearby local market.

3.2.2.3 Storage structure used

Metal bin of 2 kg capacity designed specially for the purpose (13 cm length and 14.5 cm diameter) were used as storage structure for experimentation.

3.2.2.4 Design of experiment

The experiment was designed on Completely Randomized Design (CRD) and consistedof nine treatments with single factor with three replication. The metal bins were selected as storage structure and Neem oil, Clove oil, Citronell oil, Mentha oil, Eucalyptus oil, Commercial Bojho oil, French basil oil, Malathion and Control were nine treatments.

Thus there were altogether 27 metal binsused and each metal bin was an experimental unit containing ½ kg of chickpea seeds. Each of the metal bins with ½ kg of chickpea seeds were treated with assigned treatments as per the design and then covered with muslin cloth from inside and capped tightly externally. In each experimental unit, 15 pairs of newly emerged adult bruchids (1: 1 male: female ratio) were inoculated.Male and female were distinctlyidentified by observing them under microscope by their antennae as male had pectinate type and female had serrate type. Aditionally, the post abdominal plate

(Pygidium), which is enlaged and dark color in femaleand male has smaller and lacking stripes.

Table 1. Summary of treatments (Pesticidal materials) used in bioassay experiment at AFU, Rampur, Chitwan, 2015

Treatment details	Concentration (dose) used
Neem (*Azadiracta indica*) Oi l(T_1)	3 ml / kg of seed
Clove (*Syzygium aromaticum*) Oil (T_2)	2ml / kg of seed
Citronella (*Cymbopogon nardus* Oil (T_3)	2.5 ml / kg of seed
Mentha (*Mentha arvensis*) Oil (T_4)	2 ml / kg of seed
Eucalyptus (*Eucalyptus sps*.) Oil (T_5)	3ml / kg of seed
Bojho oil (Blending of different oils) (T_6)	1 ml / kg of seed
French basil (*Ocimum basilicum*) Oil (T_7)	2 ml / kg of seeds
Malathion dust (T_8)	1 gm / kg of seeds
Control (T_9)	-

Layout of the design (CRD)

T_2R_2	T_5R_1	T_6R_1
T_6R	T_8R_1	T_9R_1
T_9R_2	T_5R_2	T_7R_1
T_7R_2	T_8R_2	T_3R_1
T_7R_3	T_3R_2	T_4R_3
T_3R_3	T_6R_3	T_1R_2
T_9R_3	T_4R_2	T_1R_3
T_2R_1	T_1R_1	T_5R_3
T_2R_3	T_4R_1	T_8R_3

T = Treatments used in the experiment, R = Replication number

3.3 Fumigation experiment

The experiment consisted of seven treatments with single factor in Completely Randomized Design (CRD) and with three replications. Transparent plastic pots of size 12 cm height and 8 cm diameter were used for fumigation experiment. Neem oil, Clove oil, Citronell oil, Mentha oil, Eucalyptus oil, Commercial Bojho oil and French basil oil were used as fumigating materials. According to design, there were altogether 21 structures of transparent plastic pot were used in the whole experiment. Ten freshly produced adults were put in to the plastic pot and essential oil were applied by using filter paper.

Table 2. Essential oils used as fumigating agent against *C. chinensis* at AFU, Rampur, Chitwan, 2015

Essential oils	Concentration (Dose)
1. Neem (*Azadiracta indica*) Oil (T_1)	0.2ml/lit air
2. Clove (*Syzygium aromaticum*) Oil (T_2)	0.2ml/lit air
3. Citronella (*Cymbopogon nardus* Oil (T_3)	0.1ml/lit air
4. Mentha (*Mentha arvensis*) Oil (T_4)	0.1ml/lit air
5. Eucalyptus (*Eucalyptus*sps.) Oil (T_5)	0.1ml/lit air
6. Bojho oil (Blending of different oils) (T_6)	0.1 ml/lit air
7. French basil (*Ocimum basilicum*) Oil (T_7)	0.2 ml/lit air

Layout of the design (CRD)

T_5R_3	T_2R_1	T_1R_3
T_5R_1	T_3R_1	T_1R_1
T_6R_3	T_2R_3	T_7R_1
T_7R_3	T_3R_3	T_4R_3
T_1R_2	T_2R_2	T_4R_1
T_3R_2	T_6R_2	T_6R_1
T_4R_2	T_7R_2	T_5R_2

T = Treatments used in the experiment, R = Replication number

3.4 Observation and data recording

The total number of dead adult bruchids after treatment setup were recorded at 15 Days after treatment (DAT). In the same time numbers of eggs per fifty seeds from each experimental unit were also recorded. Fifty seeds were randomly selected from each experimental unit. Adult emerged (both live and dead) from each experimental unit were counted on 45 and 75 DAT. Adult counted at each observation were thrown out at each observation. At the same time numbers of eggs per fifty seeds were also recorded. Initial moisture and germination percentage of the seeds were taken prior to the experimental setup. Moisture percentages were recorded on 45 DAT and 75 DAT and germination percentage were observed on75 DAT of experiment setup.

Wile Moisture Meter was used for the measurement of seed moisture and germination percentage was analyzed by using blotting paper method. For the percentage loss assessment, 100 grain sample were taken randomly at the end of observation followed

by counting of damaged and undamaged grains. Weights of damaged and undamaged grains were recorded with the help of electronic balance.

Total numbers of dead adults were recorded at 12 hours, 24 hours, 36 hours and 48 hours and cumulative mortality percent was calculated using the following formula:

$$\text{Percentage mortality} = \frac{\text{Number of dead adults}}{\text{Total number of adult inoculated}} \times 100\ \%$$

3.5 Analysis of germination percent

In order to determine the germination of seeds, a random sample of 50 seeds from each experimental unit were taken. Seeds were cleaned properly and homogenously distributed in petridish (8.8cm) coated with over soaked blotting paper. All the plates were kept in germination chamber under normal room temperature of 28^0C. Finally, germination percentage was calculated using the following formula:

$$\text{Germination percent} = \frac{\text{Number of germinated seeds}}{\text{Total number of seeds}} \times 100\ \%$$

3.6 Loss assessment

The activity was done simply using the count and weight method as adopted by Joost et al. (1996). For this, the number and weight of damaged and undamaged grains of composite sample of 100 grains were taken from each experimental unit at final observation. The percent weight loss was calculated using the following formula:

$$\text{Percent loss in weight} = \frac{(Wu \times Nd) - (WD \times Nu)}{Wu \times (Nd + Nu)} \times 100\ \%$$

Where,

Wu = weight of undamaged seeds

Nu = number of undamaged seeds

Wd = weight of damaged seeds

Nd = number of damaged seeds

3.7 Weather records

Maximum and minimum temperature, rainfall and humidity were also recorded throughout the experimental period. The daily weather recorded (Appendix 20).

3.8 Data management and analysis

Survey data were arranged and analyzed by using IBM SPSS Statistics 21 and biological parameters were arranged in Microsoft EXCEL program and statistically analyzed by using MSTATC statistical package. The data on insect population and egg count per fifty seeds were transferred square root. Similarly, data with higher CV were square root transferred. Abbott's correction was used in case of adult mortality in control treatment (Abbott, 1925).

$$\text{Corrected \%} = \frac{\text{N in T after treatment}}{(1 - \text{N in Co after treatment})} \times 100\ \%$$

Where: N = Insect population, T = treated, Co = control

4 RESULTS

4.1 Survey findings

4.1.1 Composition of respondent

Questionnaire survey was conducted at Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district. Total 45 farmers who have been involving in cereals and grain legume cultivation were selected and interviewed. Out of total farmers, 15 farmers per VDC were randomly selected for interview.

4.1.2 Sex of respondent

Out of the total respondents, 37(82.2%) were female and rest 8(17.8%) were male.

4.1.3 Composition of family member

The number of total family members in the household is given in Table 1, which indicates that majority of the household had family members of 5-7 and few households had > 8 family members.

Table 3. Composition of family member of Ramghat, Latikoili and Lekhgaun of Surkhet district

	Households with number of family members							
	3	4	5	6	7	8	9	Total
Frequency	3	4	9	13	7	6	3	45
Percent	6.7	8.9	20	28.9	15.6	13.3	6.7	100

(Source: Survey, 2015)

4.1.4 Household economy

Household economy of farmers of survey area were scored as per VDC profile of respective VDCs. Survey showed that, from the point of view of economic condition majority of people of survey area were of medium class (42.2%), pro-poor and poor were equally distributed, while only 13.3% farmers were from relatively high economic class (Table 4).

Table 4. Household economic level of Ramghat, Latikoili and Lekhgaun VDCs of Surkhet

	Household economic category				
	Pro-poor	Poor	Medium	High	Total
Frequency	10	10	19	6	45
Percent	22.2	22.2	42.2	13.3	100

(Source: Survey, 2015)

4.1.5 Land holding

Farmers of survey area possessed both upland and low land for crop production, where majority of farmers had upland for cultivation. Among the upland, majority of farmers (57.7%) owned quite small share, i.e. 0.05 to 0.2 hectare of cropping area followed by land area of 0.5 to 0.75 hectare. Only few farmers possessed land area less than 0.05 hectare and more than 0.75 hectare. In case of low land, majority of farmers (60.1%) had land area of 0.05 to 0.2 hectare of land for crop production followed by famers (24.3%) with land area of 0.5 to 0.75 hectare.

Table 5. Average land holding of farmers of Ramghat, Latikoili and Lekhgaun VDCs of Surkhet

	Land holding (ha)						
	<0.05	0.05-0.2	0.25-0.5	0.5-0.75	0.75-1	> 1	Total
Lowland							
Frequency	6	26	11	1			45
Percent	13.3	60.1	24.3	2.2			100
Upland							
Frequency	2	26	13	2	2		45
Percent	4.4	57.7	29	4.4	4.4		100

(Source: Survey, 2015)

4.1.6 Major crops grown in that area

Majority of farmers grew rice (46.7%) followed by wheat (42.2%) and maize (11.1%). Besides these crops, legume crops such as chickpea, pea and lentil were also grown in survey areas.

Table 6. Major crop cultivated in Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

	Major cultivated crops			
	Rice	Wheat	Maize	Total
Frequency	21	19	5	45
Percent	46.7	42.2	11.1	100

(Source: Survey, 2015)

4.1.7 Harvesting months

Table 5 represents the harvesting month of major cultivated crops in Ramghat, Latikoili and Lekhgaun VDCof Surkhet of Nepal. Majority of farmers of surveyed area harvested rice in the month of October (64.4%) followed by November (28.9%) and September (6.7%). Similarly, majority harvested wheat (77.8%) in April while rest were harvested in March (22.2%). Majority of the farmers harvested maize in October (88.9%) followed by September (8.9%) and November (2.2%).

Majority of farmers harvested chickpea in May (57.8%) followed by April (24.4%) and March (17.8%). Similarly, majority of pea were harvested in May (55.6%) followed by April (42.2) and March (2.2%). Similar case were recorded in case of lentil, where majority of farmers harvested in April (71.1%) and remaining in March (28.9%).

Table 7. Harvesting months of selected crops in surveyed area in Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

	Crop harvesting months											
	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Total
Rice									3(6.7)	29(64.4)	13(28.9)		45(100)
Wheat			10(22.2)	35(77.8)									45(100)
Maize									4(8.9)	40(88.9)	1(2.2)		45(100)
Chickpea			8(17.8)	11(24.4)	26(57.8)								45(100)
Pea			1(2.2)	19(42.2)	25(55.6)								45(100)
Lentil			13(28.9)	32(71.1)									45(100)

(Source: Survey, 2015)

4.1.8 Farmers practices prior to storage

Majority of farmers dry crops before cleaning, threshing and winnowing. Nearly half of the farmers (40%) adopted common storage practices of rice which included barn sanitation, while others (33.3%) adopted sun drying for threshed rice and some practiced botanicals use (26.7%) before storage (Figure 3).

Farmers followed several practices in case of wheat. The common practices were sun drying, botanicals, use of ashes and store sanitation. Study showed that majority of farmers practiced application of wood ashes (42.2%) followed by use of botanicals (22.2%), sun drying (20%) and other practices (13.3%). Similarly, over three-fourth of farmers (75.6%) practiced store sanitation followed by other practices (15.6%) and sun drying (8.9%). Survey showed that application of mustard oil was the major practices in stored chickpea (68.9%) followed by lentil (51.1%) and pea (44.4%) (Figure 3).

Figure 3. Practices before storage in selected crops of surveyed area in Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

4.1.9 Sun drying

Sun drying of seed was one of the best practices of protecting storage grain against store pests in survey VDCs. Farmers of the surveyed VDCs followed the sun drying, which is presented in Table 8. Almost half of the farmers (48.9%) practiced 1-2 times sun drying during entire storage period, while only few farmers (13.3%) followed 3-4 times for draying. Over one-third of the respondents (37.8%) didn't adopt the sun drying practices in rice.

There was great variation in sun drying of wheat in surveyed area. One-third farmers (33.3%) practiced for 3-4 times sun drying; nearly one-third farmers (29.9%) practiced no drying, others (22.2%) practiced for 1-2 times drying and remaining farmers (13.3%) practiced 5-6 times drying of wheat. In case of maize, majority of farmers (46.7%) didn't practice sun drying before storage, while 42.2% farmers practiced sun drying only for 1-2 times and remaining farmers (11.1%) followed sun drying for 3-4 times.

Sun drying was not common practice for pulses in survey areas. However, sun drying of chick pea was practiced by 44.4% farmers, sun drying of lentil by 22.2% farmers and sun drying of pea by 11.1% farmers with 1-2 days of sun drying before storage (Table 8).

Table 8. Number of sun drying in different crops before storage by the farmers of Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

	Farmers practices of sun drying of crops					
	No drying	1-2 times	3-4 times	5-6 times	7-8 times	Total
Rice	17(37.8)	22(48.9)	6(13.3)			45(100)
Wheat	13(28.9)	10(22.2)	15(33.3)	6(13.3)	1(2.2)	45(100)
Maize	21(46.7)	19(42.2)	5(11.1)			45(100)
Chickpea	25(55.6)	20(44.4)				45(100)
Pea	40(88.9)	5(11.1)				45(100)
Lentil	35(77.8)	10(22.2)				45(100)

(Source: Survey, 2015); figure in parenthesis represents percentage value

4.1.10 Type of storage structures

Infestation of storage pests also depends on storage structure. There were various types of storage structures were in practice in storage of different crops. In rice, majority of farmers (42.2%) used wooden structure followed by plastic sac (24.4%) and jute sac (17.8) respectively. Only few farmers used bamboo/ straw structure for storage of rice (Table 9).

The study showed that in case of wheat majority of farmers (73.3%) used plastic sack followed by plastic bin (17.8%) and metal bin (6.7%) respectively. But in case of maize, majority of farmers (60%) used plastic bin followed by plastic sack (28.9%), sometime bamboo structure (6.7%) and jute sack (4.4%) respectively (Table 9).

Nearly two-third farmers (60%) used plastic bin, about one-third farmers (28.9%) used plastic sack and remaining farmers (6.7%) used metal bin to store chickpea. Similar result were recorded in pea and lentil storage, where majority of farmers used plastic sack and jute sack, and plastic bin as storage structure (Table 9).

Table 9. Storage structures used by farmers of Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

	Farmers using different types of storage structures							
	Jute sack	Plastic sack	Plastic bin	Metal bin	wooden structure	Straw/bamboo	Earthen pot	Total
Rice	8(17.8)	11(24.4)			19(42.2)	4(8.9)	3(6.7)	45(100)
Wheat	1(2.2)	33(73.3)	8(17.8)	3(6.7)				45(100)
Maize	2(4.4)	13(28.9)	27(60)			3(6.7)		45(100)
Chickpea		14(31.1)	20(44.4)	11(24.4)				45(100)
Pea	19(42.2)	15(33.3)	11(24.4)					45(100)
Lentil	15(33.3)	16(35.6)	14(31.1)					45(100)

(Source: Survey, 2015); Figure in parenthesis represents percentage value

4.1.11 Pest status in different crops

Majority of farmers (55%) agreed rice moth was the major pest of rice, while over one-third of farmers (40.6%) mentioned weevil and almost all farmers (80%) claimed granary weevil as the major pest of wheat in store (Figure 4). Similarly, nearly two-third of farmers (64.4%) reported that maize weevil was the major pest of maize followed by rice moth (17.8%) and granary weevil (17.8%). In case of legume, almost all farmers (93.3%) reported pulse beetle as major pest of chickpea similarly they also reported that pulse beetle (62.2%) was the major pest of pea and lentil beetle (66.7%) was the major pest of lentil. Few farmers reported that granary weevil also damage legumes sometimes.

Figure 4. Major storage pest present in different crop in Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district

4.1.12 Pest ranking

Pulse beetle was the major storage pest of pulses in survey area. The survey result showed that pulse beetle mostly found in chickpea followed by pea and it was also found in lentil too. Cereal storage pest are generally specific to crops. So, majority of the farmers (40%) ranked chickpea pulse beetle as major storage pest followed by lentil beetle (22.2%), grain moth (20%) and grain weevil (17.8%), respectively (Table 10).

Table 10. Storage pest ranking in Ramghat, Latikoili and Lekhgaun of Surkhet district

	Pest ranking				
	Grain moth	Grain weevil	Pulse beetle	Lentil beetle	Total
Frequency	9	8	18	10	45
Percent	20	17.8	40	22.2	100

(Source: Survey, 2015)

4.1.13 Management practices

Different botanicals were used by farmers in stored grains of different crops. In case of wheat, about one-third of the farmers (33.3-35.6%) used neem and bojho, followed by some farmers (15.6%) used timur and titepati, while very few farmers (2.2%) used bojho and timur for maize storage (Table 11). In the study area, majority of farmers didn't use botanicals in legume store; rather they used chemical pesticide for grain store pest management.

Table 11. Use of botanicals by farmers of Ramghat, Latikoili and Lekhgaun of Surkhet district

Number of farmers using different plant materials for pest management in store							
	Bojho	Neem	Timur	Titepati	Banmara	Use no one	Total
Rice	11(24.4)	8(17.8)	3(6.7)	2(4.4)	21(46.7)		45(100)
Wheat	16(35.6)	15(33.3)	7(15.6)	7(15.6)			45(100)
Maize	1(2.2)		1(2.2)			43(95.6)	45(100)
Chickpea	7(15.6)	4(8.9)	2(4.4)			32(71.1)	45(100)
Pea	6(13.3)	1(2.2)	5(11.1)			33(73.4)	45(100)
Lentil	2(4.4)	1(4.4)	7(15.6)			34(75.6)	45(100)

(Source: Survey, 2015): a figure in parenthesis represents percentage value

4.1.14 Efficiency of botanicals

The study showed that majority of farmers (44.4%) viewed good efficiency of botanicals (>50%) for the management storage pest followed by other farmers (15.5%), who replied that efficiency was very good (100%), while other remaining farmers (13.3%) gave their opinion on efficiency of botanicals less than 50% (Table 12). About one fourth farmers (26.7%) viewed that botanical had no efficiency for storage pest management.

Table 12. Efficiency of botanicals used in different crops in Ramghat, Latikoili and Lekhgaun of Surkhet district

Efficiency of botanicals (%)					
	0%	100%	>50%	<50%	Total
Frequency	12	7	20	6	45
Percent	26.7	15.6	44.4	13.3	100

(Source: Survey, 2015)

4.1.15 Efficiency of chemicals

Again, just over one-third of the farmers (35.6%) viewed that use of chemicals in storage pest management was worthless, while just less than one-third farmers (28.9%) replied less than 50% efficacy. Some farmers (15.7%) indicated 100% efficacy of chemical pesticide, and some (17.8%) gave their opinion on 50% efficacy of used chemical pesticide as well (Table 13).

Table 13. Efficiency of chemical pesticide used in different crops in Ramghat, Latikoili and Lekhgaun of Surkhet district

	Efficiency of chemical pesticide (%)				
	0%	100%	> 50%	< 50%	Total
Frequency	16	7	9	13	45
Percent	35.6	15.6	20	28.9	100

(Source: Survey, 2015)

4.1.16 Pesticide use trend

The study showed that nearly three-fourth of farmers (73.3%) used chemical pesticide for storage pest management while remaining about one-third farmers (26.7%) did not use at all (Table 14).

Table 14. Farmer's perception about use of chemical pesticide in Ramghat, Latikoili and Lekhgaun of Surkhet district

	View of farmers using and not using chemical pesticides		
	Yes	No	Total
Frequency	33	12	45
Percent	73.3	26.7	100

(Source: Survey, 2015)

Among the pesticide user, majority of farmers (40%) were using pesticide since 5 years followed by 37.8% of farmers were using for 10-15 years. Very few farmers (8.9%) were using pesticides for long time, i.e. 15-20 years (Table 15).

Table 15. Pesticide used duration in Ramghat, Latikoili and Lekhgaun of Surkhet district

	Experience of pesticide use (year)				
	0-5	5-10	10-15	15-20	Total
Frequency	18	6	17	4	45
Percent	40	13.3	37.8	8.9	100

(Source: Survey, 2015)

4.1.17 Efficiency of same dose of pesticide

Majority of farmers (962.2%) of surveyed area viewed that same dose of pesticide works now. However, over one-third of farmers (37.7%) responded same dose not working as before (Table 16).

Table 16. Pesticide used trend of Ramghat, Latikoili and Lekhgaun of Surkhet district

	Farmers response on pesticide use		
	Yes	No	Total
Frequency	28	17	45
Percent	62.2	37.7	100

(Source: Survey, 2015)

4.1.18 Health related problem and nature

Farmers replied health related problems due to use of chemical pesticide. Various problems experienced by the farmers due to use of chemical pesticide were: headache (20%), skin irritation (8.9%) and eye irritation (13.3%) (Table 17).

Table 17. Response of farmers of Ramghat, Latikoili and Lekhgaun of Surkhet toward health effects of chemical pesticide used in storage

	Farmers response about effect of pesticide on health		
	Yes	No	Total
Frequency	17	28	45
Percent	37.8	62.4	100

(Source: Survey, 2015)

Table 18. Nature of health problem of farmers of Ramghat, Latikoili and Lekhgaun of Surkhet district

	Farmers response on health problem due to pesticide				
	Unknown	Headache	Skin irritation	Eye irritation	Total
Frequency	26	9	4	6	45
Percent	57.8	20	8.9	13.3	100

(Source: Survey, 2015)

4.1.19 Storage pest trend and damage status

Pest problem in storage grain was increasing at increasing order and farmers were compelled to use chemical pesticide for their management as responded by almost all farmers (Table 19).

Table 19. Storage pest infestation trend in Ramghat, Latikoili and Lekhgaun of Surkhet district

	Farmers response to storage pest trend			
	Same	Increasing at increasing order	Increasing	Total
Frequency	1	24	20	45
Percent	2.2	53.3	44.4	100

(Source: Survey, 2015)

4.1.20 Effect of climate change on storage pest and climate factor most unstable

Almost all farmers (80%) experienced climate change and its consequences on storage pest infestation, while few farmers were unknown about the present situation of climate change (Table 20).

Table 20. Response of farmers of Ramghat, Latikoili and Lekhgaun of Surkhet towards climate change

	Farmers perception on climate change		
	Yes	No	Total
Frequency	36	9	45
Percent	80	20	100

(Source: Survey, 2015)

Majority of farmers (40%) viewed that rainfall was the most unstable factor followed by temperature (33.3%) and drought (22.2%) that influence pests and create favorable environment for survival of storage pest and their infestation (Table 21).

Table 21. Response of farmers of Ramghat, Latikoili and Lekhgaun of Surkhet towards instability of climate

	Farmers response to climate components				
	Drought	Temperature	Rainfall	Humidity	Total
Frequency	10	15	18	2	45
Percent	22.2	33.3	40	4.4	100

(Source: Survey, 2015)

4.1.21 Farmers perception of climate change on storage pest trend

Based on the response, majority of farmers (46.7%) viewed that pests were also seen in cooler months and grain damage increased as the pest density increased as perceived by some farmers (Figure 5).

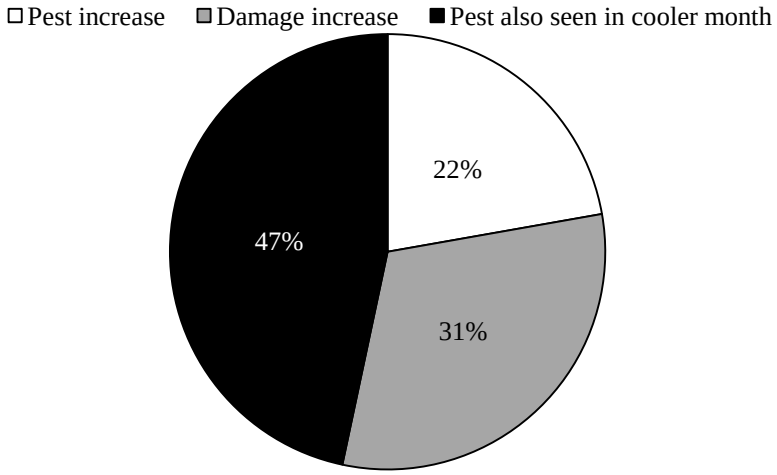

Figure 5. Storage pest infestation trend in Ramghat, Latikoili and Lekhgaun of Surkhet district

4.2 Experimental findings

The lab experiment was set up at 15th April, 2015 and was completed by 28th June, 2015. Data were recorded at 15 days (29th April, 2015), 45 days (29th May, 2015) and 75 days (28th June, 2015) after experiment setup.

4.2.1 Observations of adult beetles

Twenty freshly emerged adult pulse beetle were observed under microscope and result showed that there were 9 male and 11 females. Qazi (2007) conducted a research on development and monthly percent damage of *Callosobruchus chinensis* L. and found that out of total adult emerged, the male count was 167 in comparision with that of females which was 158. Although the number of male was slightly higher than that of female, the sex ratio was close to 50:50.

4.2.2 Study of the efficacy of different treatments

4.2.2.1 Effects of different treatment on adult mortality

There was significant difference ($P < 0.05$) on the adult mortality of *C. chinensis* among different treatments (Table 22).

Table 22. Effects of different treatments on adult mortality of *C. chinensis* at 15 DAT in chickpea seeds at AFU, Rampur, Chitwan, 2015

Treatments	Dead adults of *C.chinensis* at 15 DAT
	Number of dead adults (%)
Neem Oil @ 3ml/kg	16.00[b] (44.00)
Clove Oil@ 2ml/kg	15.33[bc](41.32)
Citronella Oil @ 2.5ml/kg	27.67[a](90.68)
Mentha Oil@ 2ml/kg	26.67[a](86.68)
Eucalyptus Oil@3ml/kg	24.33[a](77.32)
Bojho Oil@1ml/kg	15.0[bc](40.00)
French basil Oil@2ml/kg	12.33[c](29.32)
Malathion@ 1gm/kg	27.33[a](89.32)
Control	5.00[d](0.00)
Mean	18.85
SEM±	3.22
LSD	3.07
CV%	9.52

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation. Figures in the parenthesis are abbots corrected percent mortality values

The adult mortality was higher with the use of Citronella oil (27.33 adults/50 seeds), Eucalyptus oil (26.67 adults/50 seeds), Mentha oil (24.33 adults/50 seeds), which were comparable with Malathion (27.67 adults/50 seeds). In terms of adult mortality, Neem oil (16.00 adults/50 seeds), Clove oil (15.33 adults/50 seeds) and Bojho oil (15.00 adults/50 seeds) were of intermediate types, while French basil oil resulted in the lowest adult mortality (12.33 adults/50 seeds). However, among all the treatments, the lowest number of adult mortality was observed in control (5.00 adults/50 seeds).

4.2.2.2 Effects of different treatments on egg laying capacity

The treatments were differed significantly ($P<0.05$) at each observation, i.e.15 DAT, 45 DAT and 75 DAT (Table 23).

Table 23. Effects of different treatment in different days on fecundity of *C. chinensis* in chickpea at AFU, Rampur, Chitwan, 2015

Treatments	Eggs laid by *C. chinensis* in chickpea at indicated date		
	No of egg/50seeds		
	15 DAT	45 DAT	75 DAT
Neem Oil @ 3ml/kg	16.00^{bc}	94.67^{b}	269.30^{b}
Clove Oil@ 2ml/kg	22.00^{b}	36.33^{c}	79.00^{c}
Citronella Oil @2.5 ml/kg	4.00^{d}	5.00^{e}	4.33^{c}
Mentha Oil @ 2ml/kg	4.33^{d}	6.66^{e}	6.00^{c}
Eucalyptus Oil @3ml/kg	9.66^{cd}	13.00^{de}	12.33^{c}
Bojho Oil @1ml/kg	14.00^{c}	20.00^{cde}	30.00^{c}
French basil Oil@2ml/kg	15.67^{bc}	22.33^{cde}	23.33^{c}
Malathion @ 1gm/kg	12.33^{c}	29.67^{cd}	52.67^{c}
Control	42.00^{a}	134.70^{a}	526.7^{a}
Mean	15.56	40.26	111.52
SEM±	2.28	6.95	26.78
$LSD_{0.05}$	6.79	20.66	79.56
CV%	25.48	29.91	41.59

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

At 15 DAT, the lowest number of eggs were observed in Citronella oil treated chickpea seeds (4.00 eggs/50 seeds) followed by Mentha oil treated chickpea seeds (4.33 eggs/50 seeds), Eucalyptus oil treated seeds (9.66 eggs/50 seeds), Malathion dusted chickpea seeds (12.33 eggs/50 seeds), Bojho oil treated seeds (14.00 eggs/50 seeds), French basil oil treated chickpea seeds (15.67 eggs/50 seeds), Neem oil treated seeds (16.00 eggs/50 seeds), respectively and maximum no of egg were observed in control, i.e. without any treatments(42.00 eggs/50 seeds).

The trend was similar at 45 DAT, where the least number of eggs were observed in Citronella oil treated chickpea seeds (5.00 eggs/50 seeds) and then egg count gradually increased in Mentha oil treated chickpea seeds (6.66 eggs/50 seeds), Eucalyptus oil treated chickpea seeds (13.00 eggs/50 seeds) Bojho oil treated chickpea seeds(20.00 eggs/50 seeds), French basil oil treated chickpea seeds (23.33 eggs/50 seeds), Malathion dust treated chickpea seeds (29.00 eggs/50 seeds), respectively. Then maximum number of eggs

were recorded on Clove oil treated chickpea seeds (36.33 eggs/50 seeds), Neem oil treated chickpea seeds (94.67 eggs/50 seeds) and Control (134.70 eggs/50 seeds), respectively. Even at 75 DAT, the lowest number of eggs were observed in Citronella oil treated chickpea seeds (4.33 eggs/50 seeds), followed by Mentha oil (6.00 eggs/50 seeds), Eucalyptus oil (12.33 eggs/50 seeds) French basil (23.33 eggs/50 seeds), Bojho oil (30.00 eggs/50 seeds), Malathion dust (52.00 eggs/50 seeds) Neem oil (269.30 eggs/50 seeds), and the highest number of eggs were recorded in control (526.70 eggs/50 seeds).

4.2.2.3 Effects of different treatments on adult emergence

There existed significant differences ($P<0.05$) on adult emergence among the treatments both at 45 DAT and 75 DAT (Table 24).

At 45 DAT, the least number of adult emergence were observed in Citronella oil treated chickpea seeds(11.67), which slightly higher in Mentha oil treated chickpea seeds (14.00)and Eucalyptus treated chickpea seeds (29.67), respectively followed by French basil oil treated chickpea seeds (60.67), Bojho oil treated chickpea seeds (68.00), Malathion dust treated chickpea seeds (81.00). Adult emergence was found to be higher in Clove oil treated chickpea seeds (235.00) and maximum number of adult emergence were observed in Neem oil treated chickpea seeds (311.70) and in Control (345.00).

The trend was similar at 75 DAT, the lowest numbers of adult emergence were observed in Citronella oil treated chickpea seeds (7.00), which slightly higher in Mentha oil treated chickpea seeds (10.33), Eucalyptus oil treated chickpea seeds (11.67) followed by Bojho oil treated chickpea seeds (52.00), French basil oil treated chickpea seeds (52.33), Clove oil treated chickpea seeds (202.00). The maximum number of adult emergence were observed in Neem oil treated chickpea seeds (1800.00), were observed slightly higher in Control (2183.00).

Table 24. Effect of different treatments on adult emergence in chickpea at AFU, Rampur, Chitwan, 2015

Treatments	Number of adults emerged at different date	
	45 DAT	75 DAT
Neem Oil @ 3ml/kg	311.70[a]	1800.00[b]
Clove Oil@ 2ml/kg	235.00[b]	202.00[c]
Citronella Oil @ 2.5ml/kg	11.67[e]	7.00[d]
Mentha Oil@ 2ml/kg	14.00[e]	10.33[d]
Eucalyptus Oil@3ml/kg	29.67d[e]	11.67[d]
Bojho Oil@1ml/kg	68.00[cd]	52.00[cd]
Frech basil Oil@2ml/kg	60.67[cd]	52.33[cd]
Malathion@ 1gm/kg	81.00[c]	108.70[cd]
Control	345.00[a]	2183.00[a]
Mean	128.51	491.92
SEM±	13.21	56.50
LSD	39.24	167.90
CV%	17.80	19.90

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

4.2.2.4 Effects of different treatment in percent grain damage

The treatments showed highly significant difference ($P<0.05$) on percent chickpea seed damage at 75 DAT (Table 25).

Minimum percent of damaged seeds were observed in Citronella oil treated chickpea seeds (1.667), which slightly higher in Mentha oil treated chickpea seeds (2.33), Eucalyptus oil treated chickpea seeds (3.33), French basil oil treated chickpea seeds (4.33), Bojho oil treated chickpea seeds (5.00). Clove oil treated chickpea seeds (12.33) and Malathion dust treated chickpea seeds (14.67) showed intermediate effects in percent grain damage, percent of grain damage were observed slightly higher in Neem oil treated chickpea seeds (33.67). Maximum percent of grain damage were observed in control treatment (94.33).

Table 25. Effects of different treatment in percent grain damage of chickpea seeds at AFU, Rampur, Chitwan, 2015

Treatments	Percent grain damage of chickpea at 75 DAT
	Percent damage seeds
Neem Oil @ 3ml/kg	33.67[b]
Clove Oil@ 2ml/kg	12.33[cd]
Citronella Oil @2.5 ml/kg	1.67[e]
Mentha Oil@ 2ml/kg	2.33[e]
Eucalyptus Oil@3ml/kg	3.333[de]
Bojho Oil@1ml/kg	5.00[de]
French basil Oil@2ml/kg	4.333[de]
Malathion@ 1gm/kg	14.67[c]
Control	94.33[a]
Mean	19.07
SEM±	2.94
LSD	8.74
CV%	26.71

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

4.2.2.5 Effects of different treatment in percent weight loss

The treatments showed significant difference ($P < 0.05$) on percent weight loss on chickpea seed at 75 DAT (Table 26).

There were no significant difference on percent weight loss of chickpea seeds among the treatments, i.e. Citronella oil, Mentha oil, Eucalyptus oil, Bojho oil and French basil oil, minimum percent of weight loss were observed in Citronella oil treated chickpea seeds (0.28), but slightly higher in Mentha oil treated chickpea seeds (0.39), French basil oil treated chickpea seeds (0.56), Eucalyptus oil treated chickpea seeds (0.73), Bojho oil treated chickpea seeds (0.84), respectively. Whereas Clove oil treated chickpea seeds (2.06) and Malathion dust treated chickpea seeds (2.45), Neem oil treated chickpea seeds (5.62) showed intermediate effects in percent weight loss in chickpea seeds. The maximum percent of weight loss in chickpea seeds were observed in Control treatment (15.67).

Table 26. Effects of different treatments in percent weight loss of chickpea seeds at 75DAT at AFU, Rampur, Chitwan, 2015

Treatments	Percent weight loss of chickpea at 75 DAT
	% loss in weight
Neem Oil @ 3ml/kg	5.62[b]
Clove Oil@ 2ml/kg	2.06[cd]
Citronella Oil @2.5 ml/kg	0.28[e]
Mentha Oil@ 2ml/kg	0.39[e]
Eucalyptus Oil@3ml/kg	0.73[de]
Bojho Oil@1ml/kg	0.84[de]
French basil Oil@2ml/kg	0.56[de]
Malathion@ 1gm/kg	2.45[c]
Control	15.76[a]
Mean	3.19
SEM±	0.49
LSD	1.46
CV%	26.71

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

4.2.2.6 Effects of different treatments on moisture percent

The initial moisture recorded was 12.8%. The treatments showed highly significant difference ($P<0.05$) on seed moisture both at 45 DAT and 75 DAT (Table 27).

At 45 DAT, Minimum moisture percent were observed on Mentha oil treated chickpea seeds (13.2) which slightly higher in Citronella oil chickpea seeds treated (13.37) followed by Eucalyptus oil treated chickpea seeds (13.63), Neem oil treated chickpea seeds (13.6). Clove oil treated chickpea seeds (13.80), French basil treated chickpea seeds (13.97), and Malathion dust treated chickpea seeds showed intermediate effects in maintain moisture in chickpea seeds. Maximum moisture was observed in control treatment (15.5). Similar trend were recorded at 75 DAT, Where moisture percent were properly maintained in Citronella oil treated chickpea seeds(13.77), than after moisture percent were increased slightly and were observed in Mentha oil treated chickpea seeds(13.83). Moisture percent were observed intermediate in Clove oil treated chickpea seeds (14.97), Eucalyptus oil treated chickpea seeds (15.23), Bojho oil treated chickpea seeds (15.97) while moisture

percent were observed higher in chickpea seeds treated with French basil oil (16.68) and Malathion dust (17.33). Maximum percent of moisture were observed in Control treatment (18.90).

Table 27. Effects of different treatments on moisture percent of chickpea seeds at AFU, Rampur, Chitwan, 2015

Treatments	Moisture percent of chickpea seed (%)		
	Initial	45 DAT	75 DAT
Neem Oil @ 3ml/kg		13.60^{cde}	15.83^{c}
Clove Oil@ 2ml/kg		13.80^{bcd}	14.97^{d}
Citronella Oil @2.5 ml/kg		13.37^{de}	13.77^{e}
Mentha Oil@ 2ml/kg	12.80	13.20^{e}	13.83^{e}
Eucalyptus Oil@3ml/kg		13.63^{cde}	15.23^{cd}
Bojho Oil@1ml/kg		14.10^{b}	15.97^{c}
French basil Oil@2ml/kg		13.97^{bc}	16.87^{b}
Malathion@ 1gm/kg		14.20^{b}	17.33^{b}
Control		15.50^{a}	18.90^{a}
Mean		13.93	15.86
SEM±		0.14	0.26
LSD		0.42	0.77
CV%		1.77	2.84

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

4.2.2.7 Effects of different treatments on physiological loss

Initial germination percent recorded was 93.5%. The treatment showed highly significant difference ($P< 0.05$) on physiological loss of chickpea seeds at 75DAT (Table 28).

At the 75 DAT, Maximum germination percent were maintained in Citronella oil treated chickpea seeds (90.33) which slightly lower in Mentha oil treated chickpea seeds (87.00) followed by Mentha oil (87.00), Eucalyptus oil treated chickpea seeds (86.33). Germination percent were observed lower in Bojho oil treated chickpea seeds (77.67), Malathion dust treated chickpea seeds (72.67), French basil oil treated chickpea seeds (66.00), Neem oil treated chickpea seeds (64.67), and Clove oil treated chickpea seeds (64.33). Minimum percent of germination was observed in Control treatment (48.67).

Table 28. Effects of different treatments on germination percent of chickpea at 75 DAT at AFU, Rampur, Chitwan, 2015

Treatments	Germination percent of chickpea seeds	
	Initial	75 DAT
Neem Oil @ 3ml/kg		64.67[d]
Clove Oil@ 2ml/kg		64.33[d]
Citronella Oil @2.5 ml/kg		90.33[a]
Mentha Oil@ 2ml/kg		87.00[ab]
Eucalyptus Oil@3ml/kg	93.50	86.33[ab]
Bojho Oil@1ml/kg		77.67[bc]
French basil Oil@2ml/kg		66.00[d]
Malathion@ 1gm/kg		72.67[cd]
Control		48.67[e]
Mean		73.07
SEM±		2.72
LSD		11.00
CV%		8.78

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

4.2.2 Fumigant toxicity of essential oils

Different treatment showed highly significant differences ($P<0.05$) on percent mortality of *C. chinensis* (Table 29).

At 12 hours of fumigation, mortality were observed in the order of maximum in Eucalyptus oil (70.00) followed by Citronella oil (60.00), Mentha oil (50.00), Clove oil (43.33), Bojho oil (40.00), French basil oil (36.67) and Neem oil (26.67). Similar trend were observed in 24 hours of fumigation, where cumulative adult mortality were observed maximum in Eucalyptus oil (90.00) followed by Citronella oil (83.33), Mentha oil (66.67), Clove oil (63.33), Bojho oil (60,00), French basil oil (60.00) and Neem oil (43.33), respectively.

Similarly, at 36 hours total adult mortality percent were observed in Eucalyptus oil (100.00) followed by Citronella oil (97.67), Mentha oil (76.67), Clove oil (76.67), Bojho oil (76.67), French basil oil (70.00) and Neem oil (50.00), respectively.

Table 29. Fumigation effects of different treatment on *C. chinensis*

Treatments	Cumulative Mortality of *C. chinensis* (%)			
	12 hrs.	24 hrs.	36 hrs.	48 hrs.
Neem oil @ 0.2 ml/lit air	26.67[d]	43.33[c]	50.00[c]	60.00[c]
Clove oil@ 0.2 ml/lit air	43.33[c]	63.33[b]	76.67[b]	86.67[ab]
Citronella oil@ 0.1 ml/lit of air	60.00[ab]	83.33[a]	96.67[a]	100.00[a]
Mentha oil@ 0.1 ml/lit of air	50.00[bc]	66.67[b]	76.67[b]	86.67[ab]
Eucalyptus oil @0.1 ml/lit of air	70.00[a]	90.00[a]	100.00[a]	100.00[a]
Bojho oil@0.1ml/lit of air	40.00[cd]	60.00[b]	76.67[b]	86.67[ab]
French basil oil@0.2ml/lit of air	36.67[cd]	60.00[b]	70.00[b]	80.00[b]
Mean	46.67	66.67	78.09	85.71
SEM±	4.88	5.04	5.49	5.345
LSD	14.80	15.29	16.66	16.21
CV%	18.11	13.09	12.18	10.80

Mean is the average of three replication of population, SEM is the standard deviation from mean value, LSD is the least significance difference and CV denotes the coefficient of variation

At 48 hours, total mortality percent was observed also in Citronella oil (100.00) followed by Mentha oil (86.67), Clove oil (86.67), Bojho oil (86.67), French basil oil (80.00) and Neem oil (60.00). Based on the cumulative adult mortality percent, the order of fumigation effects was found to be, Eucalyptus oil > Citronella oil > Mentha oil > Clove oil > Bhojo oil > French basil oil > Neem oil.

5 DISCUSSION

5.1 Discussion of storage grain pest survey

Storage pest survey with pre-tested semi structured questionnaire was conducted at Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district in January, 2015. Total of 45 farmers were selected for survey interview with 15 purposively selected farmers from each VDC. Survey result showed that rice was the major crop cultivated in survey area, however wheat and maize also contribute major portion of food. Besides these, legumes like chickpea, pea and lentil also have significant contribution.

Study showed that sun drying was the major prevention practices before storage, however some farmer use botanicals and other practices. Use of mustard oil was the major practices adopted by farmers for the protection of legume in storage condition. Sun drying was also practiced by farmers mostly for cereal grains before storage; however it was not practiced in case of legume. Plastic sac, Jute sac and plastic bins were the major storage structure used by farmers of surveyed area. Metal bins, wooden structure, straw structure and earthen post were used by very few farmers. Metal bins are used for storage of stocked and useful for prevention of the pest attack. Ali, Latif, & Ali, (2009) reported that tin containers and plastic bags proved to be best in storing the wheat grains as compared to the gunny bags and earthen pots. Baloch, Grapher, & Ricco, (1994) reported that jute bags are the reason of high infestation of insects in the grains. In contrast, the plastic bins and metal containers do not allow any air to flow in and also maintain the moisture content, thus keep the insect infestation low (Ali et al., 2009).

Rice moth, maize weevil and granary weevil were major storage pest of cereal grains in storage of surveyed area, however pulse beetle was found to be most destructive storage pest which cause significant loss in all types of legume.

For the management of storage pest, farmers of surveyed area used both chemical pesticide and botanicals. Bojho dust, neem dust, and timur were the major botanicals used, however titepani and banmara were also used by some farmers. Most of the farmers don’t used botanicals, they practiced to use mustard oil in legume grain to protect form storage pest. Malathion and aluminium sulphide (Celphos) were the most used chemicals by farmers of surveyed area. People use Manual putting/wrapping method of the phenyl Tablets and fumigation of phosphine Tablets in the storage rooms. Previous research

revealed that phosphine and methyl bromide were the two main grain protectants in storage all around the world (Rajendran & Sriranjini, 2008).

It was found that botanicals were works good than chemical pesticide against storage pest in long term and also the efficiency of chemicals becomes lower in year after year and finally pest become resistant with chemicals. It was found that nearly 73.3% farmers used chemical pesticide for storage pest management. Among them 40% used since 5-10 years, 37.7% use since 10-5 yeas and only about 9% farmer were using them since 15-20 years. Majority of farmers (62.2%) of survey area showed that same dose of pesticide works now and about one third viewed that it didn't work. It was found that efficiency of chemicals was not significantly different from that of botanical pesticide but problems related to environment pollution and health hazards made them to inferior over botanicals.

Farmers of survey area feel some health related problems like headache, skin irritation, and eye irritation due to the use of chemical pesticide. Farmers of survey area prominently perceive the effect of climate change in storage pest infestation and majority of farmers viewed that storage pest were also found in cooler months too. And the infestation trend was at increasing orders and farmers heavily depend on chemical pesticide for the management of storage pest management. Similar finding was reported by (Ghimire, 2007) in which global warming allows pest migration or population expansion that may adversely affect the status of the pests, cost of plant protection, doses of pesticides and safety of food products.

It is expected, global warming will lead increased numbers of agricultural, structural and forest insect pests with extremes of weather like longer droughts, larger and more frequent storms, increased rainfall with the effects on plant growth (Quarles, 2007).Milder and shorter winters mean that warm weather pests will start breeding sooner (Deka, Byjesh, Kumar, & Choudhary,2010).Other effects will be changes of pest ranges, disruption of synchrony between pests and natural enemies and increased frequency of pest out breaks and upheavals (Reddy, 2015).

5.2 Discussion of experiment part

Essential oil showed significant difference over other treatments in terms of adult mortality, egg count per fifty seeds, adult emergence, percent grain damage, percent weight loss, moisture content and germination percent of chickpea seeds.

Out of 30 adult inoculated in each experimental units, higher adult mortality were recorded in the use of Citronella oil (27.33 adults/50 seeds), Eucalyptus oil (26.67 adults/50 seeds), Mentha oil (24.33 adults/50 seeds), which were comparable with Malathion (27.67 adults/50 seeds).

Essential oils showed significant effects on fecundity in all dates of date observation. Citronella oil, Mentha oil and eucalyptus oil found to be equally effective in reducing fecundity in all date of observation. Malathion found to cause higher mortality but was less effective in reducing fecundity. French basil oil, Bojho oil, Neem oil and clove oils found to be less effective in reducing fecundity at initial period, however found better than Malathion at the end of the experiment. Efficiency of Neem oil in reducing fecundity was greatly decreased at the end of the experiment. Similar effects were observed in case of adult emergency, where minimum number of adult emergence were observed in Citronella oil, Mentha oil and Eucalyptus oil treated chickpea seeds. French basil oil, Bojho oil and Malathion were found moderate in controlling adult emergence and were better than Clove oil and Neem oil in reducing adult emergence.

The percent damage seeds and percent weight loss of chick pea seeds were observed minimum in chickpea seeds treated with Citronella oil, Mentha oil and Eucalyptus oil respectively. Similarly, minimum percentages of physiological loss were observed in chickpea seeds treated with Citronella oil, Mentha oil and Eucalyptus oils respectively. Similar results were observed in case of moisture percent, where Citronella oil and Mentha oil able to maintain optimum moisture percent of chickpea seeds in comparison to other essential oil against initial moisture percent.

So, among the essential oil used Citronella oil, Mentha oil and Eucalyptus oils found to be excellent in terms of adult mortality, reducing fecundity, reduction of F_2 generation, and other seed qualities. Other oils Clove oil, French basil oil, Bojho oil showed intermediate effects while Neem oil showed lowest efficiency in comparison to other oils. Malathion dust initially caused higher adult mortality and efficient but later it was found less efficient in reducing fecundity and becomes effective in F_2 generation.

Srivastava, Gupta, & Agrawal, (1988) tested the essential oils of *Mentha arvnesis*, *Eucalyptus golobulus*, *Cymbopogon winterianus* and *C. maritinii* against *C. chinensis* on seeds of red gram (*Cajanus cajan*). At a concentration of 0.1% *C. martini* was the most effective in preventing oviposition (18.66 eggs/adult 90 days after insect release). At 0.2%, *M. arvensis* was effective and gave complete control of oviposition. Similar result was

obtained for adult emergence. They concluded that the essential oils of *M. arvensis* and *C. martini* at 0.2% and *E. globules* and *C. winterianus* at 0.4% could be used for the control of *C. chinensis* on *C. cajan.*

Similar finding was reported by Biswas and Biswas (2005) conducted a laboratory experiment on pre-storage seed treatment of gram (*Cicer arietinum*) against *Callosobruchus chinensis* L. and reported that citronella oil at 2.5ml/kg of seed effectively controlled *C. chinensis* L. population by reducing oviposition rate and the treatments also recorded the least seed damage and weight loss due to pulse beetle infestation, as well as the highest percentage of gram seed germination**.**

Nayanathara, & Ratnasekera, (2010) reported that repellent activity of Citronella (*Cymbopogon nardus* L.) oil vapour was evaluated against *Callosobruchus chinensis* L in bulk stored green gram. Citronella oil used at 2ml/kg of seed effectively controlled the population of *C.chinensis*, and this treatment has no harmful effects on germination of seed.

Sivakumar, Chandrasekaran, Vijayaraghavan, & Selvaraj, (2010) conducted an experiment to evaluate the fumigant toxicity of essential oils against pulse beetle, *Callosobruchus maculatus* F. (Coleoptera: Bruchidae). The results revealed that the lowest LD_{50} value was observed for eucalyptus oil (11.66 µll-1of air) and the LD_{50} value of geranium was the highest (25.11 µl l-1 of air).

Malathion initially was effective in causing death of adults, controlling egg number and adult emergence, but along with increase in storage period, it failed to minimize the adult emergence and their egg laying. Most, probably, this may be due to resistance developed by bruchids against Malathion.

DARP (2003) reported that Malathion resistance in stored product insect pest was found form all over the world and currently, there are 122 insect-pest species, which are found as resistant to these insecticides.

Similar result was reported byMahfuz and Khalequzzaman (2007) investigated the cardamom, cinnamon, clove, eucalyptus and neem oils against *Callosobruchus maculatus*. The results showed that mortality was more with Eucalyptus oil. The toxicity of the oils followed in the order: eucalyptus >Citronella > Mentha oil> cardamom > neem.

6 SUMMARY AND CONCLUSIONS

6.1 Summary

A research was carried out to find out the storage pest status, best farmers practices against storage pest, pesticide use trend, efficiency of pesticide, storage pest status on major cereals, farmers perception on climate change and its relationship with storage pest infestation trend in Surkhet condition and laboratory experimentation was carried out to explore the effectiveness of selected safe essential oils against chickpea pulse beetle in Chitwan condition. The survey was done with pre tested semi structured questionnaires with purposively selected 15 HH form each of the Ramghat, Latikoili and Lekhgaun VDCs of Surkhet district and experiment was designed in CRD with three replication. Seven essential oil as treatment along with Malathion, as chemical check and control (without any treatment) were used treatments in experiment to evaluate their efficiency for bruchids management.

Survey result reveled that although majority of farmers (47%) claimed that rice is major crop cultivated, Chickpea is the major in terms of economic loss caused by pulse beetle. And it is found that the major cause of heavy loss of the grain legume in the storage condition is the pulse beetle (*Callosobruchus chinensis* L.). Various practices like use of botanicas (Bojho dust, Neem dust, Timur dust/seeds, Banmara), use of chemical pesticides (Malathion dust, celphos tablet), sun drying, use of different of storage structure (Jute sac, Plastic sac, Plastic bin, Metal bin, Wooden structure, straw/bamboo structure, Earthen pot)were practiced by the farmers of surveyed area. Chemical pesticides were mostly used since 10-15 years ago by most of farmers (73.3%) but later efficiency of chemicals were decreased and their negative impacts urge farmers to use botanicals as an alternative. It is also found that efficiency and sustainability of botanicals was higher than that of chemical pestices.

Bioassay experiment result reveled that among the nine treatments tested, Citronella oil (27.67), Mentha oil (26.67) and Eucalyptus oil (24.33) were found to cause significantly higher mortality. Malathion, initially showed higher mortality (27.33) but was less effective later period especially in F2 generation with higher egg count(12.23 eggs/50seeds, 29.66 eggs/50 seeds and 52.67 eggs/50 seeds at 15 DAT, 45DAT and 75DAT respectively) and adult emergence (81.00 and 108.7 at 45DAT and 75DAT respectively). Thus, against hazardous chemical pesticide, Malathion, as storage pest

management, essential oils like Citronella oil, Mentha oil and Eucalyptus oil are found to be more economical, potential and safe pesticide for bruchids management in storage condition.

There was minimum no of egg count and adult emergence in chickpea seeds treated with Citronella oil, Mentha oil and Eucalyptus oil in all from initial to the end of the experiment. Although Neem oil, Bojho oil and Clove oil moderately work in adult mortality and reduction of egg laying, are less effective in controlling adult emergence. Neem oil is more or less equal to control in adult emergence in F_2 generation.

In the same way, percent grain damage and percent weight loss of the seed was found minimum in seed treated with Citronella oil, Menthe oil and Eucalyptus oil. Moisture percent and germination percent was highly maintained by these three essential oils.

6.2 Conclusions

Grain legume are the important component of Nepalese agriculture cropping system and has important role in terms of enhancing soil fertility and comprising a major part of dietary protein. Among the grain legume, chickpea (*Cicerarietinum* L.) is one of the important legumes grown in tarai and inner tarai in rain fed areas of Nepal. It is already traditional component of the Nepalese diet but is becoming increasingly scarce. Among the many other production constraints, insect pest are rank third based on losses. The pulse beetle is a major economically important pest of grain legume and chickpea pulse beetle is the major storage pest of chickpea.

An ecofriendly approach of managing chickpea pulse beetle (*Callosobruchus chinensis* L.) was conducted in two parts, storagegrain pest survey and laboratory test of nine treatment against chickpea pulse beetle.

In survey area, rice, wheat , maize , chickpea, pea and lentil were found to be major food grains damaged by storage pest and bruchids were found to be major among storage pest in that area. Chemical pesticides were found to be used form long time ago, were efficientat first but have many problems like pest resistance, health hazards and environmental pollution. So, farmers later started to use botanicals which were safe, easy to use and economical too. Thus botanicals are found to be the best alternatives of managing storage pest against hazardous chemical pesticides. Similarly it is found that changing climate has significant effects on storage pest status and infestation was increased

now days. Mostly storage pest infestation found to be high in summer and rainy season, however pest problem were also seen in cooler month due to shorter cooler month and increasing temperature.

In laboratory experiment, among eight pesticidal materials tested, mortality of adult bruchids was obtained significantly higher in chickpea seed treated with Citronella oil@ 2.5ml/kg (27.67) followed by Malathion dust@1gm/kg (27.33), Mentha oil@2ml/kg (26.67) and Eucalyptus oil@3ml/kg (24.33). Egg count was also low in chickpea seeds treated with Citronella oil(4.00, 5.00, 4.33) in all the dates of data recording followed by Mentha oil(4.33, 6.66, 6.00) and Eucalyptus oil(9.66, 13.00, 12.33), respectively. Among the essential oils used Citronella oil, Mentha oil and Eucalyptus oil was found to effective in controlling the adult emergence. Malathion, initially found to be effective in causing adult mortality however, is moderately effective form F_2 generation causing higher adult emergence (81.00 and 108.70). Clove oil and Neem oil becomes in effective form F_2 generation causing maximum egg count and adult emergence. Among the essential oils used, Citronella oil, Mentha oil and Eucalyptus oil found to be excellent in protecting grain damage by bruchids and also maintain the optimum seed quality.

Fumigant toxicity of essential oil used were evaluated against pulse beetle and toxicity order found to be Eucalyptus oil > Citronella oil > Mentha oil > Clove oil > Bojho oil > French basil oil > Neem oil. So Citronella oil, Eucalyptus oil and Mentha oil were found to be most effective among the used oils.

Thus essential oil extracted from various plant sources can be used as best alternatives for the management of chickpea pulse beetle (*Callosobruchus chinensis* L.) in comparison to chemicals. So these essential oils can be used while storing pulses and they may reduce the hazardous effects of chemical pesticides.

Thus, these three essential oils can be promoted as ecofriendly measures for the management of bruchids in chickpea seeds. It is hoped that they will reduce the overuse of chemical pesticide and their negative impacts like health hazard, pesticide pollution in environment and pest resistance against chemical pesticide. As Citronella oil, Mentha oil and Eucalyptus oil may not be available in all places so more plant materials having pesticidal properties are to be explored.

7 RECOMMENDATIONS FOR FURTHER RESEARCH

Essential oils are proved to have good pesticidal property. As other edible and non-edible oil, essential oils are readily available and are cheap than chemical pesticide, so further study should be focused on such essential oils for bruchids management.

Nepal is ranked 9th among the Asian countries for its floral wealth and has significantly diverse ecosystem with a wide range of unique and valuable medicinal, aromatic and insecticidal plant species. Thus, further research is recommended to explore more plant materials that have pesticidal value.

There is increasing public concern over the level of pesticide residues in food. This concern has encouraged researchers to look for alternative solutions to synthetic pesticides. Food safety is receiving increased attention worldwide as the important links between food and health are increasingly recognized. Improving food safety is an essential element of improving food security, which exists when populations have access to sufficient and healthy food.

At the same time, as food trade expands throughout the world, food safety has become a shared concern among developed and developing countries. Efforts should be made scientifically to document the pesticidal plantsand to investigate the bio-control efficacy of plant diseases of the plant products. Field trials are required to assess the practical applicability of the botanical pesticides. Biosafety studies should be conducted to ascertain their toxicity to humans, animals and crop plants.

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APPENDICES

Appendix 1. Storage pests survey questionnaires

Demography

Name of respondents:

Address: VDC: ward: settlement:

Age: Sex: Education level:

Family size:

Sex	<5yrs	6-10	11-15	16-25	26-40	41-60	>60
Male							
Female							

1. Household economic level
   a. Pro poor b. poor c. medium d. high
2. Which was your major crop?
   a. Rice
   b. Wheat
   c. maize
   d. Chickpea
   e. Pea
   f. Lentil
3. Area, Production and consumption of proposed crops

Name of legume/ Cereals	Area under cultivation		Production	Storage
	Irrigated (hectare)	Upland (hectare)		
Rice				
Wheat				
Maize				
Chickpea				
Pea				
Lentil				

4. Harvesting and storage

5. Which are the major practices you follow before harvesting? Better to rank the practices.
   i. Clean cultivation
   ii. Field drying of crop
   iii. Clean threshing and winnowing
   iv. Screening of inert and weed seeds
   v. Solar drying of seeds
   vi. Burning or removal of crop residues form field
   vii. Treating seeds
   viii. Cleaning storage barns
   ix. Any other……..
6. Have you follow any practices before storage?
   a. Yes
   b. No

   If yes

7. Which of the following practices have you been followed?
   a. Solar drying(including times of sun drying)
   b. Use of botanicals
   c. Mixing with ashes
   d. Use of mustard oil cake
   e. Storage barn sanitation
   f. Urine treatment
   g. Any other……..
8. Types of storage structures have you been used during storage?
   a. Jute sack
   b. Plastic sacs
   c. Metal bin
   d. Wooden structures
   e. Earthen pots
   f. Any other improved structures
   g. Open room storage
   h. Godwans
9. Do you seen any pests during storage?
   a. Yes
   b. No

   If yes

10. Legumes and storage pests of legumes

S.N.	Name of legumes and cereals	Name of the pests
1.	Rice	
2.	Wheat	
3.	Maize	
4.	Pea	
5.	Chickpea	
6	Lentil	

11. Rank the legumes and cereals that are more prone to storage pests infestation

S.N.	Crops	Rank	Remarks
1.	Rice		
2.	Wheat		
3.	Maize		
4.	Pea		
5.	Chickpea		
6	Lentil		

12. Which of the pest cause more damage and in which month?

S.N.	Pests	Months												Remarks
		1	2	3	4	5	6	7	8	9	10	11	12	

13. Have you been used pesticides for storage pest management?
   a. Yes
   b. No

   If yes

14. Which of pesticides have you used?
    a. Botanicals
    b. Chemical pesticides
    c. both
15. Which botanical you used for management?
    a. Bojho
    b. Neem
    c. Titepati
    d. Banmara
    e. Oils
    f. Any other
16. Which botanical works more effectively?
    a. Bojho
    b. Neem
    c. Titepati
    d. Banmara
    e. Oils

17. What about their efficiency?
    a. Works 100%
    b. Works between 50-90%
    c. Works 50%
    d. Works less than 50%
    e. Not works
18. Do you use material other than botanicals during storage like
    a. Kerosene oil
    b. Ashes
    c. Any other
    d. ……

19. Do you have used chemicals for storage pest management?
    a. Yes
    b. No
    If yes
20. Detail about chemicals.

Name of pesticides	Legume or cereal used	Dose (gm-ml/kg)	Remarks

21. Do you know about the level in chemical pesticides?
    a. Yes
    b. No
22. Do you know how to used chemical pesticides?
    a. Yes
    b. No
23. Do you use protection measures during applying chemical pesticides?
    a. Yes
    b. No
24. Mostly who used to buy the chemical pesticides?

a. Male
b. Female
c. Children

25. What is the working efficiency of chemical pesticides?
    a. 100%
    b. 50-90%
    c. 50%
    d. Less than 50%

26. Do you know about health related problems of chemical pesticides?
    a. Yes
    b. No

    If yes

27. What types of problems do you have been faced?
    a. Headache
    b. Skin irritation
    c. Chest pain
    d. Eye irrigation
    e. Faint/ unconscious
    f. Sleeplessness
    g. Vomiting
    h. Any other
28. Cost of using chemical pesticide is profitable?
    a. Yes
    b. No
29. Form when have you been used chemicals for storage pest management?
    a. 20-25 yrs
    b. 15-20 yrs
    c. 10-15yrs
    d. 5-10 yrs
    e. 0-5 yrs
30. Do you used same chemical pesticide form that time?
    a. Yes
    b. No

    If yes

31. Which and why….?

    Name of chemical pesticide……
    a. Easy access
    b. It works properly
    c. Don't know others
    d. Any other reason…….

32. Same doses of chemical pesticide works now?
    a. Yes
    b. No

If No

33. What is about pesticide efficiency?
    a. Increasing at increasing order
    b. Increasing
    c. Same
    d. Decreasing
34. Do you feel about damage trend by storage pests?
    a. Yes
    b. No

        If yes

35. What was the trend of pest?
    a. Increasing as increasing order
    b. Increasing
    c. SAME
    d. Decreasing
36. Do you feel about change in climate?
    a. Yes
    b. No

        If yes

37. Which factors of climate are most unstable now a days?
    a. Temperature
    b. Rainfall
    c. Humidity
    d. Drought

38. Do you feel any correlation of climate change with storage pest damage?
    a. Yes
    b. No

Appendix 2. List of common stored grain pests

Common Name	Scientific Name	Family	Order
Rice weevil	*Sitophilous oryzae* L.	Curculionidae	Coleoptera
	Sitophilous granaries L.	Curculionidae	Coleoptera
Khapra beetle	*Trogoderma granaruim* L.	Dermestidae	Coleoptera
	Trogoderma glabrum Herbst.	Dermestidae	Coleoptera
Lesser grain borer	*Rhizopertha dominica* Fabr.	Bostrichidae	Coleoptera
Rust red flour beetle	*Tribolium castaneum* Herbst.	Tenebrionidae	Coleoptera
	Tribolium confusum	Tenebrionidae	Coleoptera
Pulse beetle	*Pachymerus chinensis* Lin.	Bruchidae	Coleoptera
	Bruchus analis Fabr.	Bruchidae	Coleoptera
	Acanthoscelides obstectus	Bruchidae	Coleoptera
	Callosobruchus chinensis	Bruchidae	Coleoptera
	Callosobruchus maculatus	Bruchidae	Coleoptera
Maize weevil	*Sitophilus zeamais Mostch.*	Curculionidae	Coleoptera
Rice moth	*Corcyra cephalonica staint.*	Lariidae	Lepidoptera
Almond moth	*Ephestia cautella Walker*.	Pyralidae	Lepidoptera
Angonmois grain moth	*Sitotroga cerealella Oliv.*	Gelechidae	Coleoptera

Appendix 3. List of insecticidal active principles of plants

Active principle	Plant species	Insect toxicity	Insect species
Anonaine	*Annona reticulate*	Contact	*Callosobruchus chinensis*
Azadirachtin	*Azadirachta indica*	Contact: IGR	Stored grain pests, aphids
E-Anethole	*Foeniculum vulgare*	Contact	*Sitophilus oryzae, Callosobruchus chinensis*
β-Asarone	*Acorus calamus*	Contact;	Stored grain pests
Z-Asarone	*Acorus calamus; Acorus gramineus*	Contact	*Sitophilus zeamais*
Bornyl acetate	*Chamaecyparis obtuse*	Contact	*Sitophilus oryzae*
Camphor	*Ocimum kilimandscharicum*	Contact	*Sitophilus oryzae*
(+)-3-Carene	*Baccharis salicifolia*	Contact	*Tribolium castaneum*
Carvacrol	*Thujopsis dolabrata*	Contact; fumigant	*Sitophilus oryzae Callosobruchus chinensis*
Carvone	*Carum carvi*	Contact	*Sitophilus oryzae, Rhizopertha dominica*
1,8 Cineole	*Eucalyptus spp.*	Contact; fumigant	*Rhizopertha dominica Tribolium castaneum*
Cinnamaldehyde	*Cinnamomum aromaticum*	Contact	*Tribolium castaneum, Sitophilus zeamais*
Dioctyl hexanedioate	*Conyza dioscori dis*	Contact	*Tribolium castaneum, Sitophilus granaries*
Eugenol	Citrus	Fumigant	*Sitophilus oryzae*
Estragole	*Foeniculum vulgare*	Contact	*Sitophilus oryzae Lasioderma serricorne*
(+)-Fenchone	*Foeniculum vulgare*	Contact	*Sitophilus oryzae Lasioderma serricorne*

Active principle	*Plant species*	Insect toxicity	Insect species
Hexa decane	*Chenopodium ambrosioides*	Contact	*Tribolium castaneum, Sitophilus granaries*
Hexadecanoic acid	*Convolvulus arvensis*	Contact	*Sitophilus oryzae, Rhyzopertha dominica.*
Linalool	*Ocimum canum Sims*	Fumigant	*Tribolium castaneum, Sitophilus granaries*
Limonene	*Citrus*	Contact	*Tribolium castaneum*
(−)-Limonene	*Baccharis salicifolia*	Contact; fumigant	*Tribolium castaneum*
β-Pinene	*Baccharis salicifolia*	Contact	*Tribolium castaneum,*
α-Pinene	*Baccharis salicifolia*	Fumigant	*Tribolium castaneum,*
Rotenone	*Lonchocarpus sp.*	Contact; stomach poison	Crop pests, lace bugs, *Sitophilus oryzae*

Appendix 4. ANOVA of adult mortality of *C. chinensis* at 15 DAT

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	1531.407	191.426	59.408	0.000
Within	18	58.000	3.222		
Total	26	1589.407			

Mean = 18.852 CV = 9.52%

Appendix 5. ANOVA of egg count per fifty seeds of *C. chinensis* at 15 DAT

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	3144.000	393.000	25.026	0.000
Within	18	282.667	15.704		
Total	26	3426.667			

Mean = 15.556 CV = 25.84%

Appendix 6. ANOVA of egg count per fifty seeds of *C. chinensis* at 45 DAT

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	47541.185	5942.648	40.984	0.000
Within	18	2610.000	145.000		
Total	26	50151.185			

Mean = 40.259 CV = 29.91%

Appendix 7. ANOVA of egg count per fifty seeds of *C. chinensis* at 75 DAT

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	745970.741	93246.343	43.352	0.000
Within	18	38716.000	2150.889		
Total	26	784686.741			

Mean = 111.519 CV = 41.59%

Appendix 8. ANOVA of adult emergence of *C. chinensis* at 45 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	416432.074	52054.009	99.459	0.000
Within	18	9420.667	523.370		
Total	26	425852.741			

Mean = 128.519 CV = 17.80%

Appendix 9. ANOVA of adult emergence of *C. chinensis* at 75 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	17662114.519	2207764.315		0.000
Within	18	172409.333	9578.296		
Total	26	17834523.852			

Mean = 491.926 CV = 19.90%

Appendix 10. ANOVA of moisture percent at 45 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	10.896	1.362	22.228	0.000
Within	18	1.100	0.061		
Total	26				

Mean = 13.93 CV = 1.77%

Appendix 11. ANOVA of moisture percent at 75 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	66.353	8.294	40.865	0.000
Within	18	3.653	0.203		
Total	26	70.007			

Mean = 15.856 CV = 2.84%

Appendix 12. ANOVA of percent grain damage at 75 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	21564.519	2695.565	103.823	0.000
Within	18	467.333	25.963		
Total	26	22031.852			

Mean = 19.074 CV = 26.71%

Appendix 13. ANOVA of percent weight loss at 75 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	601.821	75.228	103.823	0.000
Within	18	13.042	0.725		
Total	26	614.863			

Mean = 3.186 CV = 26.71%

Appendix 14. ANOVA of germination percent at 75 DAT in chickpea

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	4445.185	555.648	13.504	0.000
Within	18	740.667	41.148		
Total	26	5185.852			

Mean = 73.074 CV = 8.78%

Appendix 15. ANOVA of percent adult mortality at 12 hours of fumigation

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	3866.668	644.444	9.022	0.0004
Within	18	1000.000	71.429		
Total	26	4866.667			

Mean = 46,667 CV = 18.11%

Appendix 16. ANOVA of percent adult mortality at 24 hours of fumigation

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	4400.000	733.333	9.625	0.0003
Within	18	1066.667	76.190		
Total	26	5466.667			

Mean = 66.667 CV = 13.09%

Appendix 17. ANOVA of percent adult mortality at 36 hours of fumigation

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	5057.143	842.857	9.316	0.0003
Within	18	1266.667	90.476		
Total	26	6323.810			
Mean = 78.095	CV = 12.18%				

Appendix 18. ANOVA of percent adult mortality at 48 hours of fumigation

Source	Degree of freedom	Sum of squares	Mean squares	F-value	Prob.
Between	8	3314.286	552.381	6.444	0.0020
Within	18	1200.000	85.714		
Total	26	4514.286			
Mean = 85.714	CV = 10.80%				

Appendix 19. Climatological data during survey period in Surkhet, 2014

Months	Avg. Max. Temp.	Avg.Min.Temp	Total Rainfall(mm)	Avg. RH(%)
January	21.4	5.6	43.2	82.5
February	23.2	7.8	41.2	80.7
March	28.1	11.4	43.7	66.1
April	33.8	15.2	10.2	52.3
May	36.2	20.0	33.5	39.3
June	36.3	23.9	85.8	57.2
July	31.4	23.8	646.8	84.4
August	31.9	23.5	799.3	83.0
September	31.9	21.7	162.4	81.6
October	29.2	16.1	32.4	78.5
November	26.5	10.6	0.0	83.5
December	22.3	5.7	29.2	86.5

Appendix 20. Daily weather records of the experimental period from April to June, 2015

April				May			
Temperature (^{0}C)		RH (%)	Rainfall (mm)	Temperature (^{0}C)		RH (%)	Rainfall (mm)
Max.	Min.			Max.	Min.		
30.75	18.75	77.00	0	32.8	23.25	78.00	0
33.15	23.7	77.00	0	32.7	21.3	75.00	23.9
32.3	20	76.00	7.3	34.2	22.2	70.00	0
31.4	19	88.00	4.3	35.3	23.6	61.00	0
31.3	19.5	64.00	0	36.3	24.2	64.00	0
32.6	18.5	61.00	0	36.85	24.5	78.00	0
30.2	19.05	64.00	0	36.5	26.25	42.00	0
32.5	20.3	78.00	0	34.1	24.3	59.00	32
34.5	19.5	42.00	0	33.3	26	54.00	0
34.7	19.1	59.00	0	33.6	26.5	75.00	0
31.8	20.95	54.00	0	34.6	26.75	76.00	0
33.2	18.5	75.00	0	35.2	24.4	77.00	0
28.7	19.5	76.00	0	35.7	26.5	76.00	0
29.15	19.9	77.00	0	37.2	29.6	76.00	0
31.8	20.3	76.00	0	37.1	27.2	85.00	0
33.25	21.2	65.00	0	37.25	24.6	71.00	0
35.2	20.75	77.00	0	37.8	25.2	78.00	0
33.1	19.95	77.00	4.9	36.7	24.75	73.00	0
31.7	22.25	73.00	0	36.6	27.75	78.00	0
33.1	25.3	72.00	0	36.5	26.25	84.00	41.9
34.1	25	71.00	0	36.1	22.5	88.00	17.4
35	22.75	71.00	0	36.3	23.65	86.00	0
34.7	21.65	79.00	0	36.6	24.6	91.00	0
34.4	21.5	77.00	0	36.6	24	77.00	0
35	21.1	76.00	0	36.15	26.5	77.00	27
29.5	22.4	71.00	0	35.65	24	77.00	15.7
32.7	22.4	72.00	0	35.25	25.3	76.00	11.4
33.8	19.5	77.00	0	35.3	25.5	88.00	0
30.2	21.25	77.00	2	35.6	27.8	64.00	0

June			
Temperature(^{0}C)		RH (%)	Rainfall(mm)
Max.	Min.		
36.3	23	78.00	0
37.65	27.5	73.00	0
37.5	27	78.00	0
36.7	25.25	84.00	0
37.5	27.3	88.00	0
38.5	28.25	86.00	0
39.1	28.4	80.00	0
38.7	27.6	73.00	0
37.6	28	78.00	3.9
37.8	30.5	84.00	0
33.8	26.3	88.00	14
32.6	27	86.00	0
33.65	25.2	71.00	30
34.15	25.15	72.00	33.7
34.7	24.7	77.00	20.9
34.35	26.65	77.00	15
35.25	26.5	64.00	16
37	28.1	78.00	0
35.25	24.15	75.00	13.7
36.2	25.75	70.00	11.2
36.15	24.6	77.00	13.5
36.25	27.5	77.00	0
35.25	27.4	64.00	2.2
34.8	27.75	85.00	7.2
34.25	25.3	82.00	50
33.75	25.15	89.00	72.5
32.25	25.7	77.00	0
30.3	26.15	77.00	0
31.35	26.3	64.00	3
33.85	28.55	77.00	0

Appendix 21. Daily records of room temperature and humidity of the experimental period from April to June, 2015

April		May		June	
Temperature (^{0}C)	RH (%)	Temperature (^{0}C)	RH (%)	Temperature (^{0}C)	RH (%)
23.50	68.00	25.00	75	28.00	85.67
24.50	69.00	26.00	74	29.00	84.00
24.50	71.00	26.00	72	30.00	80.33
24.00	70.00	26.50	68	30.00	70.67
24.50	69.00	28.00	66	31.00	79.67
25.50	68.00	28.50	67	32.00	86.67
23.00	67.00	27.00	68	32.50	84.00
23.50	65.00	26.50	67	32.00	81.00
25.00	59.00	25.00	63	32.00	71.67
24.50	63.00	27.00	65	32.50	68.33
25.00	61.00	28.00	68	29.00	65.33
25.50	64.00	28.00	79	27.50	61.67
25.00	65.00	28.50	78	26.00	70.67
23.00	63.00	30.00	75	25.00	67.00
24.00	68.00	31.00	72	23.50	62.00
24.50	70.00	30.00	71	24.00	61.67
23.00	70.00	29.50	71	23.50	64.33
23.50	68.00	29.00	67	25.00	65.67
26.00	69.00	29.50	64	25.50	71.00
27.00	70.00	27.00	60	26.00	66.33
27.50	72.00	25.00	68	25.60	70.00
27.50	73.00	27.00	73	27.00	70.67
27.00	75.00	27.50	68	28.00	67.00
25.00	75.00	29.00	65	28.50	62.00
26.50	76.00	29.50	59	24.00	63.67
24.30	74.00	28.00	61	24.50	65.33
24.00	76.00	28.50	62	25.00	61.67
23.00	75.00	28.00	68	26.50	65.67
23.50	78.00	29.00	67	26.00	64.00
24.50	73.00	29.50	63	27.50	67.00
		29.50	61.12		

BIOGRAPHICAL SKETCH

The author is the son of Mr. Padam Lal Subedi and Mrs. Batuli Subedi. He was born on Baisakh, 11, 2045 (23rd April, 1988) in Jarbuta-1, Dhuliyabit, Surkhet District, Nepal. He got his primary education form Shree Shiva Higher Secondray School, Dhuliyabit, Surkhet and School Leaving Certificate (S.L.C.) from the same school in 2004 in the first division. He completed +2 science form Shree Jana Higher Secondary School, Birendranagar, Surkhet in 2006.Then he completed four years of Bachelor's degree in Agriculture from theInstitute of Agriculture and Animal Science/TU in 2011 in the first division. The author got an opportunity to study Master's degree in Entomology at Agriculture and Forestry University in 2013. He was funded by CARITAS- NEPAL for his thesis research.

For one year after completion of his bachelor degree he worked as Livelihood Officer of Samunnati Livelihood Improvement and Community Empowerment Program conducted by Forum for People's Awareness (FOPA), Arghakhanchi with the financial support of OXFAM_HK. Then he worked as Instructor in Shree Shiva Higher Secondary School, Latikoili, Surkhetunder TSLC Programlaunched by Department of Education. He also worked as Project Coordinator in NARDF funded Buckwheat promotion project in Kalikot and Small irrigation promotion for vegetable production project in Surkhet district. Recently he was join in SAHAS-Nepal (The Group of Helping Hands) as Project Coordinator in Dailekh.

The author is interested in several extra-curricular activities, like music and playing guitar. He has keen interest in social works. The author is highly ambitious and gives first priority to his career. He believes in hard work. He is strongly determined to contribute to his birth place through his works in the coming future.

Author