INFLUENCE OF SEED PHYSICO-CHEMICAL PROPERTIES ON BRUCHID (*Callosobruchus chinensis* L.) AND ITS MANAGEMENT IN GREENGRAM

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B.Sc. (Ag.)

MASTER OF SCIENCE IN AGRICULTURE

(SEED SCIENCE AND TECHNOLOGY)

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BY
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DECLARATION

I, **G. KAVITHA,** hereby declare that the thesis entitled **"INFLUENCE OF SEED PHYSICO-CHEMICAL PROPERTIES ON BRUCHID (*Callosobruchus chinensis* L.) AND ITS MANAGEMENT IN GREENGRAM"** submitted to **Acharya N. G. Ranga Agricultural University** for the degree of **Master of Science in Agriculture** is the result of original research work done by me. I also declare that no material contained in the thesis has been published earlier in any manner.

Place: Guntur **(GANESAM KAVITHA)**

Date: **I. D. No. GAM-16-15**

CERTIFICATE

Ms. G. KAVITHA has satisfactorily prosecuted the course of research and that thesis entitled **"INFLUENCE OF SEED PHYSICO-CHEMICAL PROPERTIES ON BRUCHID (*Callosobruchus chinensis* L.) AND ITS MANAGEMENT IN GREENGRAM"** submitted is the result of original research work and is of sufficiently high standard to warrant its presentation to the examination. I also certify that neither the thesis nor its part thereof has been previously submitted by her for a degree of any university.

Date: **(M. SESHA MAHALAKSHMI)**
Chairperson

CERTIFICATE

This is to certify that the thesis entitled **"INFLUENCE OF SEED PHYSICO-CHEMICAL PROPERTIES ON BRUCHID (*Callosobruchus chinensis* L.) AND ITS MANAGEMENT IN GREENGRAM"** submitted in partial fulfillment of the requirements for the degree of '**Master of Science in Agriculture**' of the Acharya N. G. Ranga Agricultural University, Guntur, is a record of the bonafide original research work carried out by **Ms. G. KAVITHA** under our guidance and supervision.

No part of the thesis has been submitted by the student for any other degree or diploma. The published part and all assistance received during the course of the investigation have been duly acknowledged by the author of the thesis.

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Date :

Place : **(GANESAM KAVITHA)**

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LIST OF SYMBOLS AND ABBREVIATIONS

@	:	at the rate of
µg	:	Micro gram
µm	:	Micro meter
^{0}C	:	Degree Celsius
%	:	Per cent
CD	:	Critical Difference
cm	:	Centimeter
CV	:	Coefficient of variation
cv.	:	Cultivar
dSm^{-1}	:	Deci siemen per metre
et al.	:	and other people
Fig.	:	Figure
g kg^{-1}	:	Grams per kilogram
g	:	Gram
h	:	Hour
i.e.,	:	Which is to say
kg	:	Kilogram
kg ha^{-1}	:	Kilogram per hectare
mg	:	Milli gram
ml	:	Milli litre
mm	:	Milli metre
ml kg^{-1}	:	Milli litre per kilogram
mg/ g	:	Milli gram per gram
nm	:	Nanometer
N.S.	:	Non-significant
Ppm	:	Parts per million
Ph	:	Potential of H^+ ion concentration
R	:	Correlation Co-efficient
RH	:	Relative humidity
rpm	:	Revolutions per minute
SEm	:	Standard error of mean
Sig.	:	Significant
viz.,	:	Namely

ABSTRACT

Name of the Author	:	**G. KAVITHA**
Title of the thesis	:	**"INFLUENCE OF SEED PHYSICO-CHEMICAL PROPERTIES ON BRUCHID (*Callosobruchus chinensis* L.) AND ITS MANAGEMENT IN GREENGRAM"**
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The present investigation was carried out by conducting three different experiments under laboratory conditions in Regional AgriculturalResearch Station (RARS), Lam, Guntur andDepartment of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur from August, 2017 to March, 2018.All the experiments were laid out in Completely Randomized Design with three replications under ambient conditions.

The relative preference of twelve greengram genotypes by pulse bruchid, *Callosobruchus chinensis*, were assessed based on the biological parameters *viz.,* oviposition, adult emergence, mean developmental period and growth index of the test insect and weight loss of seed under no-choice test. The biological parameters of the test insect after artificial infestation were initially low but gradually increased with increase in period of storage upto eight months. The results revealed that PM-5 was less preferred, while WGG-42 was highly preferred by the pulse bruchid. Based on growth index of insect, five greengram genotypes *viz.,* PM-5, LGG-610, LGG-607, GGG-1 and LBG-595 were categorized as resistant, one as moderately susceptible and the remaining six as highly susceptible to pulse bruchid.

Studies on the influence of artificial infestation by pulse bruchid revealed significant differences for germination, seedling parameters and electrical conductivity of seed leachates among the twelve greengram genotypes throughout the storage period of eight months. PM-5 recorded highest germination, seedling length, seedling vigour index and moisture content and lowest electrical conductivity, while WGG-42 recorded lowest germination, seedling length, seedling vigour index and highest moisture content and electrical conductivity through out the storage period.

The physical parameters of seed were evaluated for all the twelve greengram genotypes *viz.,* colour, shape, surface texture, seed length and width, seed coat hardness and 100 seed weight. From the data, it was evident that the greengram genotypes with smooth texture, oblong or globose shape and light coloured seed might be less preferred

by the pulse bruchid for egg laying. The genotype, PM-5 with more length (4.77 mm), width (3.77 mm), length width ratio (1.26) and seed coat hardness (96.00%) recorded less number of eggs, long mean development period and less seed weight loss. Test (100 seed) weight of greengram genotypes under study was highest in PM-5 (4.87 g) and it was observed that test weight had non-significant influence on the incidence of pulse bruchid.

Biochemical parameters *viz.*, protein content, phenol content and sugar content were estimated from all the twelve greengram genotypes before and after eight months of storage after artificial infestation by pulse bruchid. The data showed that PM-5 having low sugar and protein content and high phenol content was resistant, while WGG-42, with high sugar and protein contents and low phenol content was susceptible to pulse bruchid.

The correlation studies between biological parameters of insect and physical and biochemical characters of seed showed that biological parameters *i.e.*, number of eggs, adult emergence and growth index had significant positive association with protein content, sugar content, moisture content and electrical conductivity and negative correlation with phenol content, 100 seed weight and seed coat hardness. In contrast, mean development period of pulse bruchid had negative correlation with protein content, sugar content, electrical conductivity and moisture content and positive association with phenol content, 100 seed weight and seed coat hardness. Multiple linear regression studies revealed that all the physical and biochemical properties of seed together contributing to a large and significant variation in growth and development of pulse bruchid.

The breeder seed of greengram variety, LGG-460, treated with six botanicals *viz.*, turmeric powder @ 20 g kg^{-1}, neem leaf powder @ 25 g kg^{-1}, neem seed kernel powder @ 5 g kg^{-1}, coconut oil @ 5 ml kg^{-1}, inert dust @ 5 g kg^{-1} and fly ash @ 10 g kg^{-1} and malathion dust (recommended insecticide) @ 1 g kg^{-1} (check) along with untreated control seed was used to evaluate their efficacy as seed protectants against pulse bruchid.All the seed protectants used in the present study were significantly superior to untreated seed and were able to protect the greengram seed upto eight months of storage. Highest mortality of adult beetles, lowest number of eggs, adult emergence and seed weight loss were recorded from seed treated with coconut oil and malathion. Among the different seed protectants, turmeric powder and fly ash registered the lower mortality of adult beetles, highest number of eggs and adult emergence.

Irrespective of the seed protectants used for seed treatment, the seed quality parameters like germination, seedling length and seedling vigour index decreased, while electrical conductivity and moisture content increased progressively over the period of storage. All the seed protectant treatments significantly improved the germination and seedling growth compared to that of untreated seed through out the storage period of eight months. However, non-significant variation in seed moisture content was observed between the seed treatments. Among the seed protectants evaluated, highest germination, seedling length and seedling vigour index and lowest electrical conductivity and moisture content were recorded in seed treated with botanical product, coconut oil @ 5 ml kg^{-1}which was found as effective as insecticide check, malathion dust @ 1 g kg^{-1}.

Chapter – I

Introduction

Chapter I

INTRODUCTION

Greengram(*Vigna radiata* L. Wilczek) commonly known as mungbean, belonging to the family leguminaceae, is a herbaceous short duration crop, mostly grown under semi-arid and subtropical climate. The crop is believed to be native of India and Central Asia (Vavilov, 1951). The seed have high digestible protein content (22-24 %) and does not cause any flatulence as some other legumes (Malik, 1994). Moreover, it is rich in vitamins such as A, B, C, niacin and minerals such as potassium, phosphorus and calcium which are necessary for human body.

Greengram is the third important pulse crop cultivated throughout India, being rich in quality protein, minerals and vitamins, which are inseparable ingredients in the diet of a vast majority of Indian population. When supplemented with cereals, they provide a perfect mix of essential amino acids with high biological value. It is grown mainly as *kharif* crop in Rajasthan, Maharashtra, Karnataka, Orissa and Tamil Nadu, as *rabi*/*spring* crop in Tamil Nadu, Bihar, Orissa, Uttar Pradesh, West Bengal, Maharashtra and Karnataka and as summer crop in Uttar Pradesh, Madhya Pradesh, Bihar, Jharkhand and Orissa states. But, in Andhra Pradesh it is grown as both *kharif* and *rabi* crop in uplands and in rice fallows also.

About 70 per cent of the world's production of greengram is from India, which is cultivated annually in an area of 3.83 million hectares with a total production and average productivity of 1.60 million tonnes and 418 kg ha^{-1}, respectively, during 2015-16. The total area in Andhra Pradesh is 2.12 lakh hectares contributing to an annual production of 1.37 lakh tonnes with an average productivity of 646 kg ha^{-1} during 2015-16 (AICRP on MULLaRP, 2016-17).

The pulse crops are attacked by more than 150 insect pests both in field as well as in storage. Among the storage pests, *Callosobruchus chinensis* is one of the cosmopolitan pest, which attacks wide variety of pulses. It is commonly known as pulse bruchid, which is a major storage pest of mungbean. It is a field-to-store pest as its infestation on pulses often begins in the field itself as adults lay eggs on mature pods (Huignard *et al.*, 1985) and when such seed is harvested and stored, the pest population increases rapidly and results in total destruction within a short period of three to four months (Rahman and Talukder, 2006). It is an important stored product pest of Africa, Asia and occurs throughout the tropical and subtropical countries. The infestation causes considerable losses both in terms of quality and quantity. The quality of seed is reduced by denaturing and decreasing the solubility of proteins. Both the grubs and adults cause damage. In badly damaged seed, endosperm is eaten by the grubs leaving only the thin outer covering or thin film or seed coat. On an average 2.0 to 2.5 million tons of pulses are lost annually due to insect pests. Worldwide, it is estimated that 10-40 % of stored food products are lost due to insects, fungus, bacteria and virus. India produces around 12.65 million tons of pulses per year and nearly 8.5 % of this is lost during post harvested handling and storage (Agrawal *et al.*, 1988).

Some of the external factors such as, temperature, humidity, moisturecontent, carbon-dioxide/oxygen, insects and microbial activities influenced either directly or indirectly the infestation on stored pulses. Changes in the physico-chemical properties pave the way to destruction of seed. Increase in the moisture content of the seed results in increasing insect infestation. Insect infestation leads to the loss of physical, chemical and nutritive value and also reduced the market value. Physical loss is mainly due to reduction in weight, change in appearance and colour, while the nutritive value changes due to increase in acidity, reducing sugars and uric acid due to insect attack. Insects often devour the germ portion or embryo which is more nutritive, thus reducing the germinability.

The basis of resistance involves morphological, physiological and biochemical mechanisms which range from simply minimizing the effect of insect attack to adversely affecting the growth and development of insects (Singh, 2002). There are many accessions which exhibit wide range of physical and chemical characteristics such as seed color, texture, size, hardness and chemical constituents (Lattanzio *et al.*, 2005). In many cases, it is obvious that the physical characters of seed and biochemical constituents such as phenols, tannins, trypsin inhibitor and amylase inhibitor are important in conferring resistance to bruchids. It has been suggested that such physical factors complement the biochemical factors found in bruchid-resistant cowpea varieties (Appleby *et al*., 2003).

During storage, pulses undergo some chemical changes due to the presence of insects. With increase in storage period, the bruchid infestation escalates and reduces the biochemical characters for seed quality which leads to lack of storability of seeds in storage. They alter the flavor and nutritive value of grains which reduce the marketability and acceptability of pulses. Gujar and Yadav (1978) reported 55 to 60 % losses in seed weight and 45.5 to 66.3 % losses in protein content due to bruchid infestation in storage. Patel *et al.* (2002) revealed that higher phenol content of different pulses lengthen the developmental period of *C.chinensis* and so phenols must have had inhibitory role on the developmental process of pulse beetle. The presence of texture layer also influences the bruchid damage. Morphological characters like rough seed surface texture has been reported to deter oviposition by bruchids (Messina and Renwick, 1985). The thickness and hardness of the seed coat has been suggested as one of the factors preventing the juvenile larva to gain entry into the cotyledons (Nwanze *et al.,* 1975).

In order to keep stored seed free from insect-pest infestations various synthetic pesticides are used. Although chemical insecticides are effective, but their indiscriminate use has led to residual toxicity, insecticide resistance, environmental pollution and adverse effects on food besides side effects on humans. Methyl bromide and phosphine fumigants have been used for decades to control stored pests (Mishra *et al*., 2007). Ozone depleting nature of methyl bromide has led to restriction of its use as post-harvest fumigant and the Montreal protocol of United Nations Environment Programme (UNEP) recommend the phasing out of methyl bromide by 2015 in developing countries (Anonymous, 2000). Phosphine resistance is becoming more common (Tyler *et al*., 1983) and is a matter of considerable concern. Therefore, there is a need of some other alternatives to chemical pesticides and fumigants to protect stored grains from insect-pest infestations.

Concerns about the harmful residues of insecticides in stored produce and the emergence of resistant strains of pests necessitate the search for viable non-chemical means of controlling stored product pests. Host plant resistance is one of the most promising methods of reducing bruchid infestation (Keneni *et al*., 2011). However, greengram varieties known for their superior performance in field in terms of crop pest tolerance and yield were found susceptible to pulse bruchid in storage (Swamy *et al*., 2010). Reduced oviposition, less seed damage, low adult emergence and prolonged development period of pulse bruchid were attributed to the tolerance in wild plants of greengram (Soundararajan *et al*., 2013).

Use of pesticides leads to the development of insect resistance and environmental pollution which has forced the researchers to look for some non-toxic pulse protectants. Various locally available plant products have been tried earlier with good degree of success as protectants against a number of insect pests in storage (Salam *et al*., 2005). Among various protectants, some plants have been found to posses the most effective and most acceptable active ingredients. There is an urgent need to develop pest management strategies which will be commercial and safer in small and large scale storage. These strategies could be achieved by exploiting the insecticidal properties of plants, which are also easily available to farmers. The plant materials are inevitable favourites by virtue of lesser impact on the environment.

Keeping all these views in mind, the present study is proposed with the following objectives.

Objectives of Investigation

- To study the infestation level of pulse bruchid under no-choice artificial conditions in different greengram genotypes during seed storage
- To study the physico-chemical properties of seed of different greengram genotypes against pulse bruchid
- To evaluate the effectiveness of eco-friendly material as seed protectants against pulse bruchid in greengram

Chapter – II

Review of Literature

Chapter II

REVIEW OF LITERATURE

Pulse production in India has been practically stagnant for the last few decades. The major pulse crops those have been domesticated and are under cultivation include blackgram, chickpea, cowpea, greengram, lentil, mothbean, pea, pigeonpea *etc*. Greengram (*Vigna radiata* (L) Wilczek) is under cultivation since prehistoric time in India. It is the third most popular pulse crop cultivated throughout India. Considerable basic research is needed to increase the productivity of greengram and other pulses to meet the expanding requirements. Besides low productivity, other constraints such as post-harvest technology, pest infestation, improper sanitation and storage methods cause both qualitative and quantitative losses to pulses. To avoid post harvest losses, the development of storage pest resistance cultivars is important in integrated pest management programme and for decreased probability of environmental contamination from an appropriate use of eco-friendly material.

Bruchids are very important stored pests on pulses. In India, 117 species of bruchids belonging to 11 genera have been recorded (Arora, 1977). The genus, *Callosobruchus* includes a number of economically important species that attack stored pulses throughout the world. But *Callosobruchus chinensis* L., *Callosobruchus maculatus* F. and *Callosobruchus analis* are most important in India.

A brief review of literature pertaining to the different objectives of the present study are outlined in this chapter under the following heads:

2.1 SCREENING OF GERMPLASM OF LEGUMES AGAINST PULSE BRUCHID

The pulse beetle, *C. chinensis* is a cosmopolitan polyphagous pest in the most tropics and subtropics. The pulse beetle is reported to be the most damaging pest of legume seeds which are a major source of protein in many countries. Eggs are laid on the seed surface in storage or pods in the fields and larvae develop within seed causing weight loss, decreased germination potential and reduction in commercial value. The seed may be almost completely hollowed out by feeding of the larvae and characteristic emergence holes are evident after the adult leaves the seed. Thus, severe damage and significant weight loss occurs in stored seed.

The literature pertaining to germplasm screening against resistance to bruchid in greengram is scanty, hence the available literature on other pulses is also reviewed here under:

Srinivasan and Durairaj (2008) screened fifteen greengram accessions through an intensive no-choice test for assessing their resistance to bruchids. An accession IC 39397 was comparatively resistant with lesser survival (17.59 %), prolonged development time (31.92 days) and least suitability index (0.0390) when compared to CO 6, a cultivar which was used as check for the study. Accessions like IC 52049 and PLM 292 were moderately resistant. Hence these accessions can be used as a source of resistance for evolving bruchid resistant varieties.

Deshpande *et al*. (2011) evaluated 35 genotypes of cowpea both at initial as well as 90 days after infestation for their relative response to the attack by *C. maculatus* with artificial infestation and classified as high, moderate and least susceptible groups based on seed damage. Comparatively least susceptible genotypes were IC 202784, IC 212872, IC 4506 and IC 198701, while highly susceptible genotypes were IC 214757, IC 98361 and Mumbai local and rest of the genotypes were moderately susceptible for bruchid attack.

Gupta and Deo (2011) screened ninety genotypes of cowpea for bruchid resistance under laboratory conditions and observations were recorded for total number of eggs laid, per cent adult emergence and extent of seed damage. Thirty genotypes out of ninety exhibited moderate level of resistance which can be used for further screening.

Shivanna *et al*. (2011) evaluated seven different cowpea varieties *viz*., C-152, KBC-2, KBC-1, KM-5, IT-38956, TVX-944 and CP-17 for their preference to *C. maculatus* and *C. analis.*Among them, CP-17 was comparatively less preferred host with lesser oviposition (81.33 eggs/ 100 g seeds), prolonged developmental period (34.67 days), least adult survival (84.67 %) and weight loss of grains (0.96 %) followed by IT-38956 to *C. maculatus*. Similar trend was observed with lesser oviposition (65.33 eggs/ 100 g seeds), prolonged developmental period (36.83 days), least adult survival (59.33 %) and grain weight loss (0.90 %) on CP-17 when compared with local variety in case of *C. analis*. C-152 and local variety were recorded as preferred hosts for both the species.

Divya *et al*. (2013a) studied relative resistance / susceptibility of 50 horsegram accessions to the attack of *C. chinensis.*Based on mean developmental period, Palem-2, Palem-1, AK-21 and NSB-27 were categorized as resistant, NS/05/42 and NSJ/NAIP/BD-ADB-35-1 were found susceptible. On the basis of susceptibility index, Palem-2, KSAS/06/391, Palem-1, AK-21, NSB-27, NSJ/NAIP/140-239 and NDS-259 were categorized as resistant, while NS-74, RJR-94, PSRJ-13089, NS/05/113, NSM-125and PSRJ-13089-1 were grouped as moderately resistant. NSJ/NAIP/031-130, BAR-231-1, NSJ/NAIP/006-105, PSRJ-13030, NS/05/94 and NS/05/87 were classified as highly susceptible to bruchid infestation.

Among the twenty eight *Dolichos* bean genotypes screened by Prasad *et al*. (2013) against *Callosobruchus theobromae*, GL 77 recorded the lowest seed damage (13.4 %), followed by GL 233 (14.69 %) and GL 63 (18.34 %) which were grouped as least susceptible. The highest seed damage was observed in GL 46 (97 %) at par with GL 67 (44 %) and GL 127 (42.75 %) which were grouped as highly susceptible. None of the entries were completely free from bruchid damage.

Chakraborty *et al*. (2014) conducted an experiment on host preference of *C. chinensis* on different pulses consecutively for two generations in the laboratory at 30±1 ^{0}C and 70±5 % R.H. The results revealed that kidneybean was the least preferred host for the bruchid as the developmental period was prolonged and adult emergence was the lowest which might be due to some secondary substances which need further investigation. Cowpea was the most preferred pulse while greengram and pea were also proven to be good hosts for the insect but blackgram was recorded as moderately susceptible.

Obadofin (2014) assessed seventeen cowpea varieties suitable for intercropping with cereals for their resistance to *C.maculatus* attack under laboratory conditions. There were significant differences ($p<0.05$) among the varieties tested with respect to the parameters used. IT89KD- 288, IT99K-429-2 and IT97K-356-1 were resistant to *C.maculatus* while IT97K-461-4, IT97K-570-18, IT99K-1122, IT98K- 205-8, IT99-1060, IT98-1399 and Ife Brown were susceptible.

Radha and Susheela (2014a) investigated on the life history and ovipositional preference of *C.maculatus* reared on five different pulsesand concluded that cowpea seeds are the most vulnerable legume seeds and the most suitable hosts. Cowpea seed had the maximum number of eggs laid, shortest developmental period, highest susceptibility index and maximum weight loss.

Sharma and Thakur (2014b) studied the comparative growth performance of *C. maculatus* on genotypes of different legumes (cowpea, chickpea and soybean). The results revealed that all the legume genotypes of soybean (except Harasoya) and cowpea with smooth seed coat texture were highly preferred by *C. maculatus* for egg laying than chickpea genotypes (kabuli>desi). Among all the genotypes of three legumes highest percentage of adult emergence, growth index, percentage reduction in weight and low developmental period was recorded in cowpea followed by chickpea (kabuli>desi) and least in soybean which may be due to physical and chemical factors that resist the growth and development of *C. maculatus* on soybean genotypes.

An investigation was conducted by Chakraborty *et al*. (2015) on the life history and ovipositional preference, nature of damage caused by *C.chinensis* reared on five different pulses through two successive generations. The results indicated that based on the susceptibility indices kidney bean (0.72) and blackgram (4.90) were considered as resistant and non-suitable hosts for *C. chinensis*. Small pea (6.54) was found to be moderately resistant, while cowpea (12.84) and greengram (12.32) were most suitable hosts for the development of *C. chinensis* among the pulses investigated.

Choudhary *et al*. (2015) screened ten cowpea varieties for their reactions against *C. chinensis* in storage. Among them 'Pusa Phalguni' had the lowest number of adult emergence (3.62) followed by 'Divya-405' (4.25) and 'RCV-7' (5.95). On the basis of per cent weight loss due to infestation of *C. chinensis,*'RCV-7' was found superior with lowest (1.73 %) per cent weight loss after six months of cowpea storage followed by 'Divya-405' (1.76 %) and 'Pusa Phalguni' (1.82 %). Significantly lower germination loss was recorded in 'Pusa Phalguni' (14.03 %), 'Anand-1' (14.61 %) and 'Divya-405' (14.66 %). Based on the above three parameters, the varieties 'Anand-1', 'Anand-5', 'RCV-7', 'RC-101', 'Divya-405' and 'Pusa Phalguni' were found to be highly resistant against *C. chinensis* under storage.

Osman *et al*. (2015) investigated the suitability of five common pulse species (chickpea, cowpea, field bean, pea and white bean) to infestation by *C. maculatus.*Results indicated that the tested pulse species differed in their susceptibility to infestation with pulse beetle. Cowpea seed were the most susceptible, followed by chickpea and peas; however, white bean and faba bean seed showed high degree of tolerance even under heavy pulse beetle infestation. Cowpea seed was more favorable for oviposition and extended longevity of pulse beetle adults compared to chickpea and pea seed.

Tripathi *et al*. (2015) screened 52 accessions of cowpea including two checks (Pusa Komal and Local variety) for resistance to pulse beetle under no-choice artificial infestation conditions. Based on growth indices, Pusa Komal (0.04081) and IC 328859 (0.04112) were resistant, while IC 106033 (0.06819) and local variety (0.06816) were most susceptible. Of the 52 accessions screened, eleven accessions were resistant, fifteen were moderately resistant, thirteen were moderately susceptible, eight were susceptible and five were highly susceptible to pulse bruchid.

Ahmad *et al*. (2016) conducted an experiment on the growth and development of the pulse beetle on 11 chickpea varieties. Results revealed that the fecundity of the pulse beetle female varied significantly on different chickpea varieties, minimum being on PBG 1 (59 eggs/100 seeds) and maximum on PKG 1 (81 eggs/ 100seeds). The development period for eggs (5.33-7 days), larva (17-18.67 days) and pupa (5.67-7.33 days) on different varieties did not differ significantly. However, significant variation in the total development period from eggs to adult (28.67-32.33 days) was recorded in different varieties. Similarly the growth index of the pulse beetle varied significantly on various varieties (0.52-0.71). The results of study showed that the chickpea variety PKG 1 was most suitable for growth and development of the pulse beetle.

Padmavati *et al*. (2016) screened 51 accessions of different *Lens spp*. for their reaction to *C. chinensis* under no-choice artificial infestation conditions. Based on growth Index (GI), accessions were categorised as highly resistant (15 accessions, GI = 0.00), resistant (14, GI = 0.00 to 1.00), moderately resistant (16, GI = 1.01 to 2.00) moderately susceptible (three, GI = 2.01 to 3.00) and susceptible (three, GI > 3.01) to pulse bruchid.

Parmar and Patel (2016) screened mungbean germplasm for their susceptibility against *C. chinensis* L. under storage. Among the mungbean varieties; vishal, samrat, GM-3, GM-4 and K-851 were found resistant based on oviposition preference, population growth, per cent weight loss and per cent germination loss.

Sharma *et al*. (2016a) conducted an experiment on the preference of pulse beetle on five different pulses *viz*., blackgram, greengram, chickpea (Desi), cowpea and pea. The beetle laid maximum eggs (89.3) on cowpea and minimum on pea (50.7). Hatching of eggs was maximum on green gram (98.1 %) and minimum on cowpea (94.3 %). No significant differences were found in oviposition period, post-oviposition period, incubation period, total life period and adult longevity on various pulses. The adult emergence was maximum on chickpea (96.7 %) and minimum on pea (52.3 %).

Shinde *et al*. (2016) studied the preference, growth and development of pulse beetle on fifteen cowpea varieties. Results revealed that the genotype KN-KL-3 (41.5 eggs/ 20 g seed) was comparatively less preferred by *C.maculatus* for egg laying followed by konkan safed (45) and PCP-9790 (49.5) whereas, the genotype DCP-2 was the most preferred with an average of 137.5 eggs per 20 g grains. The genotype KN-KL-3 was comparatively less susceptible with 11.26 % infestation.

Swamy *et al*. (2016) conducted an **e**xperiment to know the relative susceptibility of blackgram varieties to pulse beetle. The Trombay blackgram varieties, TU 80 and TU 68 were found resistant to the pulse bruchid. The variety LBG 752 was found susceptible to the pulse bruchid.

Choudhary *et al*. (2017) investigated qualitative losses in ten different varieties of lentil caused by the infestation of *C.chinensis*. Out of the ten varieties, Asha and PL-01 were less susceptible and Sapna, IPL-81 and L- 4076 were highly susceptible. However, L-147, RKL-60701, JL-3, RKL-607 and RKL-6118 were moderate susceptible.

Maini *et al*. (2017) assessed the quantitative and qualitative losses caused by pulse beetle during storage of chickpea seed (cultivar JG 315) in various storage structures. It was concluded that the seed with low infestation (7.25 to 9.70 %), minimum weight loss (0.28 to 2.20 %) and less moisture content (12.30 to 13.80 %) showed better germination (72.30 to 87.00 %). On the other hand, the lowest germinated (35.60 to 48.90 %) seed had high percentage of moisture, thus more infestation and weight loss.

Raghavendra and Loganathan (2017) conducted an experiment to study the effect of *C. maculatus* infestation on seeds of pigeonpea (var. SRG-09) at different days of interval (5, 10, 15 20, 25 and 30th days). The results of the experiments showed that the number of days of exposure is directly proportional to the level of insect attack. The early stage larvae did not cause much damage to the seed initially. The damage level of seeds was increasing as larva grows inside. The larva was observed in 80 per cent of the seeds on 10th day. Cent per cent infestation of seeds was observed on 20th, 25th day with larvae or pupae and on 30th day with adults. It was also observed that no seed was infested in control with any stage of the insect. The increase in moisture content was observed to the tune of 23.50 per cent due to infestation of larval / pupal stage of bruchid on 30th day. Vigour index also decreased significantly when the seeds were exposed more number of days and it was 61.5 on 30th day.

Reaction 20 genotypes of pulses belonging to lentil, mungbean, chickpea and blackgram to pulse beetle was evaluated by Mahmud *et al*. (2018) in no choice test and reported higher susceptibility of chickpea and lowest susceptibility of blackgram. Egg deposition was highest on chickpea seed when compared to other host seeds. Number of laid eggs also varied according to the surface area and chemical composition of seed.

2.2 PHYSICO-CHEMICAL BASIS OF RESISTANCE AGAINST PULSE BRUCHID IN DIFFERENT LEGUMES

The genus *Callosobruchus* iscapable of breeding on a wide variety of legumes. The process of host selection and oviposition is mainly influenced by physical and biochemical factors. The degree of resistance and susceptibility of different pulses to bruchid attack is influenced by various characteristics.

A brief review on the physico-chemical basis of resistance against pulse bruchid in different legumes is presented below:

Landerito *et al*. (1993) reported the physico-chemical and biochemical factors which could be associated with mungbean and urdbean resistance against bruchid. Resistant mungbean and urdbean were found to be 20 % to 59 % harder than the susceptible Pagasa 7 mungbean variety. The two accessions (ACC 2228 and VM 2164) of urdbean were more harder compared to the mungbean varieties (ACC 19, ACC 179 and ACC 214).

Venugopal *et al.* (2000) categorized the seed of various wild and cultivated legume varieties on the basis of their relative resistance to the bruchid, *C. maculatus* and correlated with the important primary and secondary metabolites (non-protein anti-metabolites) of these seed to the development parameters of the bruchid. All the cultivated varieties had higher amounts of primary metabolites, such as proteins, carbohydrates, lipids and free amino acids and showed a positive correlation with the infestation rate. The non-protein anti-metabolites such as total phenols, ortho-dihydroxy phenols and tannins were significantly lower in the cultivars. In contrast, the wild varieties had higher amounts of secondary metabolites showing a negative correlation with the infestation rate. The study revealed that non-protein anti-metabolites were important in conferring the resistance to the seeds.

Shafique and Ahmad (2005a) screened 22 chickpea genotypes for resistance to pulse beetle *C. analis* (F.). Grains of chickpea genotypes with wrinkled seed coat and black colour affected the beetle development and seemed to be less preferred than the smooth, plumpy and white colour seed of chickpea cultivars.

Aslam *et al.* (2006) tested six varieties of stored chickpea for their resistance against *C. chinensis* L. and concluded that Parbat was highly susceptible to bruchid as compared with Paidar-91, the susceptible standard. The variety Punjab-91 and Pb-2000 were partially resistant, while Bittle-98 was resistant to bruchid. Chemical analysis of different varieties showed variations in dry matter, moisture, crude protein, fat fiber, total mineral (ash) and tannin. The study showed that variety Bittle-98 was a promising one which can be incorporated in future management programmes against pulse bruchid.

Shaheen *et al.* (2006) evaluated the resistance of 15 chickpea cultivars against pulse beetle and concluded that the cultivars with rough, wrinkled, hard and thick seed coat were more resistant compared to those having smooth, soft and thin seed coat. The cultivars such as Bittle-98, Dasht, Punjab-91, Parbat, C-44 and C-44×E-100YM had thick seed coat, while CM-72, NUYT-90395, NCS-2003, CH-41/91, Noor-91, CM-2000, BH-73111, Paidar-91 and Flip 97-192C had thin seed coat.

Srinivasan and Durairaj (2007) screened nineteen accessions of the wild plants including rice bean *viz.*, *Vigna umbellata* Thunb. for their relative resistance to the bruchid. The results showed that the biophysical factors like 100 seed weight and seed hardness had a highly significant and negative relationship with that of index of suitability (r = -0.62 and -0.47, respectively).

Srinivasan *et al.* (2009) focussed on the evaluation of non-edible legumes for identifying resistant factors against bruchids. All the non-edible legumes had a seed hardness of more than 20 kg except *Clitoria* which registered a hardness of 18.33 kg. Further, the greenngram cultivar (CO 6) which was completely susceptible for *C. maculatus* development had a seed hardness of 5.67 kg. The seed coat thickness of different non-edible legumes was comparatively higher ranging from 81.87 µm (*Sesbania sesban*) to 304.09 µm (*Cassia robusta*) when compared to greengram (CO 6) (40.94 µm).

Fawki *et al*. (2012) screened four varieties of the cowpea (Local, Dokki 331, Kareem 7 and Aswany) for their resistance to the bruchid,*C. maculatus* F. Data revealed that the seed texture of cowpea was an important factor as an oviposition stimulus for *C. maculatus*. The average number of eggs laid by female on seed with smooth surface (79.5±5.66) was significantly (P=0.009) higher than those deposited on the other seed with wrinkled coat.

Sarwar (2012) studied the relative resistance of 12 chickpea genotypes to the attack of *C. maculatus* during storage. The most tolerant genotypes, CH-52/02 and B-8/03, exhibited hard and wrinkled seed coat, dark brown colour and small sized grain. These characteristics demonstrated a significant negative relation with pest appearance and grain damage. The most susceptible reactions were apparent in CH-86/02 and CC-117/00, which had soft and smooth seed coat, white seed colour and bigger grain size that resulted in vulnerability to pulse bruchid.

Divya *et al.* (2013b) reported the effect of biochemical and physico-chemical characters of fifty horsegram accessions on bruchids. Less protein content, high phenols and thick seed coat of the accessions were detrimental to the growth and development of *C. chinensis,* while high protein content, low phenols and thin seed coat of the test accessions favoured the successful development of bruchids on horsegram.

Siddiqa *et al*. (2013) evaluated the development of pulse beetle, *C. chinensis* on five chickpea varieties KK-1, KK-2, KC-98, Lawaghar and Sheenghar under laboratory conditions. All these varieties were different in grain size and chemical composition and their response varied significantly against *C. chinensis* infestation. Taking weight loss as a standard parameter, cultivar Lawaghar (4 % weight loss) was classified as significantly least susceptible, KK-2 (28 %) and Sheenghar (31 %) moderately susceptible and KC-98 (60 %) and KK-1 (70 %) as highly susceptible.

Tripathi *et al*. (2013) screened 52 accessions of cowpea including check (Local variety) for variability in physical and biochemical parameters of seed. Based on growth index of pulse beetle, eleven accessions *viz.,* IC 107466, IC 106815, IC 106037, IC 106812, IC 106816, IC 106817, IC 108749, IC 311138, IC 328859, IC 381583 and Pusa komal were reported as resistant to the beetle. Growth index of *C. chinensis* had insignificant relation with seed hardness and seed coat hardness and had a positive relation with seed length-width ratio, 100 seed weight and seed moisture. Phenol and tannin had negative relation with growth index of *C. chinensis,* while amylase inhibitor had a positive relation.

Amusa *et al*. (2014) assessed the bruchid tolerance of some elite cowpea varieties. Analysis of seed coat resistance indicated that there was no significant difference in number of eggs laid, mean bruchid development time, percentage bruchid emergence, percentage seed damage and susceptibility index between the smooth and rough seed coats. The study indicated that factors other than seed coat nature were responsible for bruchid resistance in cowpea.

Lazar *et al.* (2014) studied the impact of different biochemicals present in the genotypes/ varieties of greengram on the life cycle and development of pulse beetle. Total protein, free amino acid and total soluble sugars were significantly higher in seed of ML-1268, ML-1256 and KM-10-1040, while, the same biochemicals were significantly lower in seed of COGG-912, KM-10-1039 and GM-08-09. Total protein, free amino acid and total soluble sugars also showed highly significant and negative correlation with incubation period, larval-pupal period and total developmental period of *C. maculatus*. On the other hand, total phenol, tannin and flavonoid contents were found significantly higher in GM-08-09 and COCG-912 and lower in ML-1268 and ML-1256. Total phenol, tannin and flavonoid contents showed highly significant and positive correlation with incubation period, larval-pupal period and total developmental period. These anti-nutritional factors reflected higher resistance to pulse beetle.

Sharma and Thakur (2014a) studied the biochemical basis of bruchid resistance in different legume genotypes and the results revealed that highly resistant soybean genotypes possesed high amount of fats, proteins and antinutritional factors (phenols and 4-5 times more trypsin inhibitors) than cowpea and chickpea (kabuli>desi) genotypes which contain high amount of carbohydrates and low amount of antinutritional factors and were susceptible to *Callosobruchus* species.

Chandel and Bhadauria (2015) conducted an experiment to find out the impact of physical characteristics of promising varieties of pigeonpea on infestation of pulse beetle. The results indicated that mean test weight was found to be 94.35 g and most of varieties were not deviating from the mean except PRABHAT and UPAS-120. The seeds of PUSA-33(11.9), PUSA-9 (13.9), TYPE-7 and BAHAR (13.1) kg/ grain, had significantly more hardness. The average moisture content in pigeonpea varieties was found to be 12.39 per cent. The mean protein content was 22.99 per cent in pigeonpea varieties. AMAR possessed the lowest protein content (21.80 per cent) and had significantly poor protein content. It can be concluded that TYPE-7 variety of pigeonpea showing the least weight loss (15.82 %) due contained 110.13 g test weight, 13.1 kg hardness/grain, 12.5 per cent moisture and 21.80 per cent protein. It is followed by IPCL-151(17.03 %) due to 98.423 g test weight, 7.6 kg hardness/grain, 12.3per cent moisture and 22.40 per cent protein.

Parmar and Patel (2016) conducted a study on influence of physical characters of mungbean for their susceptibility against bruchid under storage. The results revealed that there was no significant relation between oviposition preference and width of seed (r = -0.053) of different varieties. Whereas, oviposition was significant and negatively correlated (r = -0.380) with the length of seed. This indicated that varieties having higher seed length were preferred less by the female adult for the oviposition and vice-versa. However, oviposition was highly significant and negatively correlated with weight of 100 seed and seed coat thickness (r = -0.433 and -0.527).

Raghuwanshi *et al*. (2016) studied the relative resistance of desiandkabulichickpea genotypes against *C. chinensis* during storage. The kabulichickpea genotypes showed susceptibility to *C.chinensis*. The seed of these genotypes were bold in size, ivory white in color, irregular round in shape with smooth texture of testa and high in protein content.

Singh *et al*. (2016) tested ten germplasm lines of chickpea for their resistance against pulse beetle. In above germplam, the chemical composition of the seed were evaluated on the basis of their storage period before and after three months of storage. The co-efficient of correlation between per cent infestation with per cent moisture content, protein content and fat content was positive significantly, and per cent germination was negative significant.

Sekar and Nalini (2017) screened fifty two genotypes of greengram for their resistance against *C. chinensis* and evaluated the biochemical basis of resistance during 2015-2016. They reported that bruchid incidence had highly significant positive correlation with total sugar and protein content of grains and negative correlation with phenol, oil content and trypsin inhibitor activity.

2.3 MANAGEMENT OF PULSE BRUCHID WITH ECO-FRIENDLY MATERIAL

Pulse beetle is a field-to-store pest as its infestation starts from field itself and continued in storage. It multiplies very rapidly in storage (Ouedraogo *et al.,* 1996) and 8.5 % loss in pulses was reported during post-harvest handling and storage in India. Effective control of beetle is possible with chemical insecticides like fumigants and dusts. But they pose many health hazards to warm-blooded animals and there was a risk of environmental contamination. Pest may also develops resistance to the chemicals after some time due to prolonged and indiscriminate use. Thus the use of plant products is considered as an important component of insect pest management because of their economic viability and eco-friendly nature. Botanicals are effective alternatives for chemical insecticides to reduce pesticide load in the environment (Radha and Susheela, 2014b).

A brief review on the efficacy of eco-friendly material on the management of pulse bruchid in different legumes is presented below:

Ojiako and Adesiyun (2007) studied the insecticidal efficiency of the powdered forms of some locally available plant materials in comparision to a conventional storage chemical, Actellic 2 % dust (Pirimiphos-methyl) against the cowpea bruchid. Data on the effects of the materials on mortality of *C. maculatus* were collected at 24 hours, 48 hours and 7 days over a seven-month period. The plant materials generally performed better than the control. The interactive effect of the plant materials was found to be dose-related. However, only *Piper guineense*, *Moringa oleifera* and *Ocimun gratissimum*, in that order, performed comparably well with Actellic dust. Actellic dust at the lowest rate inflicted adult mortality of 90-100 % in the first 48 hours after treatment whereas *Piper guineense* at the lowest rate (2.5 g/ 100 g seed) inflicted mortality of up to 90.0 % in 48 hours. *Moringaoleifera* at the medium rate (5.0 g/ 100 g seed) and *Ocimum gratissimum* at the highest rate (10 g/ 100 g seed) gave mortality of 76.7 % and 60.0 % in 48 hours, respectively.

Kar *et al*. (2008) conducted an experiment to test the effect of different botanicals against the egg laying behaviour of pulse beetle on chickpea kabuli variety, Dollar. The results showed that the leaf powder of goat weed @ 2.5 g/ 50 g of seeds was the most effective and reduced the egg laying of pulse bruchid.

Yankanchi and Lendi (2009) conducted an experiment to evaluate the efficiency of leaf powders of *Tridax procumbens, Withania somnifera, Pongamia pinnata* and *Gliricidia maculata* against the pulse beetle infestation in greengram. It was concluded that leaf powders of *T. procumbens* and *W. somnifera* showed significantly high mortality, oviposition deterrence and adult deterrence of *C. chinensis* even at very low concentrations. Hence, these leaf powders were suggested for incorporation in the integrated management of beetle infestation during storage.

Deshpande *et al.* (2010) studied the influence of plant products and insecticides on bruchid infestation during storage on seed of soybean cv. JS-335. They concluded that soybean seed should be treated with plant products such as sweet flag rhizome powder and neem seed powder instead of malathion dust or methyl parathion insecticides as the plant products are cheap, easily available, non toxic, eco-friendly and had no adverse effect on germination and seedling vigour.

Pokharkar and Chauhan (2010) tested different materials for their efficacy against the pest *C. chinensis* in stored chickpea. Treatment ash in chickpea seeds was found more effective upto four months and with neem oil upto two months on the basis of oviposition. Chickpea seeds treated with ash and neem oil were found more effective on the basis of adult mortality and adult emergence upto four months.

Sarwar (2010) tested the effect of leaf powders as grain protectants against *C. maculatus* in chickpea. Results revealed that pest mortality was directly proportional to the concentration of the botanicals used. Seed treatment with *Withania somnifera* and *Ocimum sanctum* at 2 % and 5 % concentrations were most effective against pest, while, seed treatment with *Dalbergia sisso* at 5 % was the least effective treatment.

Varma and Anandhi (2010) studied biology of pulse beetle and their management through botanicals on stored mung grains. The seven plant materials, *viz.,* neem leaf, chilli fruit, neem seed kernel, tulsi leaf, nerium leaf, lantana leaf, tobacco leaf including untreated control were evaluated for their effects against pulse beetle. Among all the plant products, neem leaf (8 g/ 100 g grains) was found more effective with 38.33 % mortality, whereas nerium leaf (4 g/ 100 g grains) was found least effective with 5.70 % mortality.

Rai and Pandey (2011) investigated the insecticidal activity of five plant products against pulse beetle in chickpea. Among them, black pepper exhibited the highest toxic effect (100 %) whereas, cinnamon bark (75-80 %), fenugreek seed (75 %)

and vitex leaves (90 %) were also proven to be effective. Turmeric powder extract, however, caused lowest toxic effect as compared to other plant products. It was also observed that the seed and barks were more efficacious than leaves and other vegetative parts tested against the pulse beetle.

Regmi and Dhoj (2011) conducted an experiment on eco-friendly approach of managing pulse beetle in chickpea and concluded that *Acorus calamus* rhizome dust @ 30 g kg^{-1}, *Cinnamom camphor* balls @ 1.5 g kg^{-1} and *Sesamum* oil @ 5 ml kg^{-1} can beusedas excellent alternatives over the poisonous pesticides for the management of *C. chinensis* L. in storage of chickpea.

Nagangouda *et al.* (2012) reported that the per cent loss in weight due to pulse bruchid was nil in sweet flag rhizome @ 2 % and malathion @ 2 % treated seeds without any adverse effects on germination in pigeonpea.

Neog and Singh (2012) screened ten different plant powders and eight vegetable oils against *C. chinensis* (L.) on greengram seeds. Among all the botanicals tested, the vegetables oils and *Azadirachta indica* kernel powder were significantly superior over rest of the treatments in reducing egg-laying and adult emergence. In case of vegetable oils, neem oil was the best treatment which reduced egg laying and adult emergence by 90.00 to 91.67 % and 85.96 to 89.06 %, respectively. In case of plant powders, *Azadirachta indica* kernel powder was found as the best treatment in reducing oviposition (75.78-80.41 %) and adult emergence (66.92-71.93 %). Seed powders of *Piper nigrum* at 5 % and *Litsea citrata* at 5 % were fairly effective while, leaf and seed coat powderof *Zanthoxylum oxyphyllum* at 5 % was the least effective followed by leaf and seed coat powderof *Melia azedarachta* at5 %.

Ramazeame *et al.* (2012) studied the efficacy of the botanicals and oils against pulse beetle in blackgram. They concluded that the neem kernel powder and pongam oil were most effective, castor oil, illupai oil and vasambu rhizome powder were effective, notchi leaf powder and coconut oil were moderately effective and adathoda leaf powder was less effective against pulse beetle.

Adenekan *et al*. (2013) evaluated the insecticidal effects of powders from different plant parts of *Moringa oleifera* for the control of bruchid in cowpea and reported that the powder of *M.oleifera* flower had some potential against bruchid as bio-insecticide.

Chandrakala *et al*. (2013) studied the toxic effect of neem leaf powder in controlling the infestation of *C. chinensis* in stored greengram seed. It was inferred that both the neem products (neem leaf powder and neem stem ash powder) play a vital role in controlling the infestation of *C. chinensis* in stored seed. Among the treatments, NLP treatments were found effective in destroying the pest. This might be due to the trait that burning of neem stem to ash might have reduced the biocidal properties of neem products.

Lazar and Panickar(2013)evaluated different plant powders and plant oils for their seed protectant efficacy against *C. maculatus* in greengram (variety GM-4) and reported that custard apple seed power, orange peel powder, coconut oil and clove oil were most effective; groundnut oil, olive oil and safflower oil were intermediate; neem seed kernel powder, chrysanthemum flower powder and pomegranate seed powder were least effective; while clove flower bud powder and red chilli fruit powder were ineffective protectants against *C. maculatus.*

Pal and Katiyar (2013) studied the efficacy of some botanical powders *viz.,* Neem leaf powder (10 and 20 g kg^{-1} seed), soapnut powder (10 and 20 g kg^{-1} seed), turmeric powder (10 and 20 g kg^{-1} seed) and vasambu rhizome powder (5 and10 g kg^{-1} seed) along with a chemical insecticide, deltamethrin (40 mg kg^{-1} seed) as post-harvest seed protectants against pulse beetle.Based on parameters like seed germination, seed moisture and insect infestation, vasambu rhizome powder (10 g kg^{-1} seed) and deltamethrin (40 mg kg^{-1} seed) were observed as most effective against pulse beetle.

Sharma *et al.* (2013) evaluated the efficacy of some botanicals against pulse beetle in chickpea after 160 days of storage interval. All the oils gave significantly higher adult mortality as compared to untreated control. On the basis of number of eggs laid, adult emergence and seed damage all treatments (neem oil, mustard oil, groundnut oil, mustard oil + turmeric powder and groundnut oil + turmeric powder) except neem seed kernel powder and turmeric powder were considered as most effective against *C. chinensis.*

Maji *et al*. (2014) evaluated the effect of six ethanolic extracts *viz.,* neem leaf, rhizome of ginger, garlic and turmeric, eucalyptus leaf and leaf of *Lantana camera* against biological parameters of pulse beetle in pea. It was observed that all the botanicals were superior over control and suppressed some biological parameters such as number of eggs/seed, eggs laid/day, oviposition period, hatchability per cent, adult formation and adult survivorship and prolonged developmental stages such as incubation period and larval-pupal period. Among the botanicals, garlic was found very effective which recorded nil adult emergence (0.00 %) followed by neem and turmeric with 4.76 and 6.67 % adult emergence, respectively.

Mandali and Reddy (2014) evaluated the efficacy of indigenous neem products for the control of pulse beetle, *C. chinensis* in stored redgram. The results indicated that the neem formulations *viz.*, Econeem plus, Neemazal and Neemindia were found very effective against *C. chinensis* by recording less oviposition, less adult emergence and less insect damage in stored redgram and also maintained high viability (>80 %) and vigour of seed up to nine months of storage.

Rana *et al*. (2014a) evaluated the efficacy of aqueous plant extracts on seed deterioration and bruchid infestation in peacv. P-89 during storage. All the quality parameters showed significant differences due to seed treatment with botanicals. The results revealed that seed treatment with aqueous extract of *Mentha spicata* recorded significantly higher germination (82.1 %), seed vigour index- I (1077) at the end of six months of storage period without insect infestation. This treatment was found on par with seed treatment with aqueous extract of *Mentha longifolia* (81.6 %, 922.25, respectively). Insect infestation was nil in all the botanicals as compared to control (17 %) after six months of storage.

Vishwamithra *et al*. (2014) conducted studies on eco-friendly management of *C. chinensis* L. in pigeonpea. The grain protectants used in the study indicated that all the 4 oils *viz.*, soyabean, sesamum, eucalyptus and karanj oil used @ 3 ml/ kg seed significantly reduced the fecundity, adult emergence and seed infestation on par with the chemical protectants deltamethrin 2.8 EC (0.04 ml / kg seed) and spinosad 45 SC (4 ppm).

Ahmad *et al.* (2015) evaluatedthe protective efficiency of bioactive neem leaf powder (NLP)against pulse beetle *(C. chinensis)* in stored mungbeangrain and prolonging effect on its shelf life. It was concluded from the results that with increase in neem leaf powder concentration, number of eggs laid, developmental period, total progeny, per cent grain damage and per cent weight loss decreased while adult mortality increased. Similarly, with the increase in storage duration, number of egg laid, developmental period, adult mortality, total progeny, per cent grain damage and per cent weight loss increased. Neem leaf powder applied at the rate of 1.5 mg/ 100 g grains performed better as compared to control and other concentrations.

Khan *et al.* (2015) conducted an experiment on eco-friendly management of pulse beetle, *C. chinensis* L. in mungbean using some promising botanicals *viz.*, dried leaf powder of neem @ 2.5 g kg^{-1}, bishkatali @ 2.5 g kg^{-1}, marigold @ 2.5 g kg^{-1}, dholkolmi @ 2.5 g kg^{-1} and chopped garlic bulb @ 1.0 g kg^{-1} along with control. Dried leaf powder of neem @ 2.5 g kg^{-1} mungbean showed the highest per cent reduction in infestation over control than other botanicals.

Raja (2015) studied the comparative performance of insecticidal and oviposition deterrence of cashew nut shell liquid (CNSL) on bruchids in cowpea seed. Experimental results showed that the cowpea seeds treated with CNSL have a significant effect on its viability and vigour during 12 months storage. The seeds treated with the lower doses *viz.*, 1, 2 and 3 ml kg^{-1}have showed stimulatory effect on germination and seedling vigour during initial period. However, the seeds treated with CNSL @ 3 ml kg^{-1}significantly (P=0.05) maintained the highergermination (df=7, F=7.2) and vigour (df=9,F=4.0) during 12 months storage when compared to other doses and untreated control.

Kumar *et al.* (2016)investigated the efficacy of some essential oils against pulse beetle infestation (*C. chinensis* L.) in pea seed. Among the six essential oils, sweet flag possessed reasonably high and immediate toxicity resulting in 78.33 % and 96.67 % mortality in 1 and 3 days after treatment. After 7 days, cent per cent mortality was observed in seeds coated with sweet flag essential oil. After 10 days of exposure, eucalyptus essential oil also resulted in complete kill even at the lowest dose (0.30 ml kg^{-1}). On day 15, mortality in control had substantially increased to 67.50 per cent.Egg laying was minimum on sweet flag essential oil treated pea seeds (5.25 eggs/5 females) on 7^{th} day of observations. In untreated pea seeds, increases in egg laying was negligible in 20 days observations (7^{th} day 94.08- 20^{th} day 101.92).

Sharma *et al.* (2016b) conducted an experiment to evaluate the effect of some plant products as surface protectants against *C. maculatus* (F.) on pigeonpea. The highest mortality (84-100 %) was manifested by neemoil @ 10 ml kg^{-1} among all the treatments, while lowest (3.33 %) was with turmeric powder @ 3.5g kg^{-1} seed after 135 days of storage. Neemoil @10 ml kg^{-1} completely inhibited oviposition, adult emergence, seed damage and also not affected seed quality as compared to other treatments. All the oils prevented egg laying, reduced population build up of beetles and minimized the seed damage as compared to control.

Singh and Pandey (2016) found that the plant based protectants *i.e.*, datura seed powder, tobacco leaf powder, bhaitt leaf powder, lemon leaf powder, ginger rhizome powder, bitter gourd seed powder, asafoetida latex, gunghchi seed powder and alocasia leaf powder were effective and significantly reduced the insect infestation, loss in germination in comparision to control in chickpea.

Suthar and Bharpoda (2016) reported that among the various botanical powders tested against pulse bruchid infestation in blackgram. Neem leaf, garlic bulb and eucalyptus leaf @ 2 per cent (w/w) recorded more than 32 per cent adult mortality, higher half-life values (>56.97 days) and higher gross persistency (>1999.48). Significantly lower numberof adults were emerged (<20.75) in treatments with these botanical powders during six months of storage period when compared to control.

Chapter – III

Material and Methods

Chapter III

MATERIAL AND METHODS

The present studywas conducted under laboratory conditions in Regional AgriculturalResearch Station (RARS), Lam, Guntur andDepartment of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur for a period of eight months from August, 2017 to March, 2018. The mean monthly meteorological data pertaining to rainfall, number of rainy days, temperature and relative humidity during the experimental period is presented in Annexure I. The details of material used and techniques adopted during the course of investigation are given in this chapter.

3.1 EXPERIMENTAL DETAILS

3.1.1 Seed Material

Seed of twelve greengram genotypes (Table 3.1) and breederseed of greengram variety, LGG-460 collected from the Regional Agricultural Research Station, Lam, Guntur were used in the present investigation. Infestation free, sound and healthy greengram seed of each greengram genotype and the variety, LGG-460 were shade dried for three days. Grain moisture was tested before start of the experiment by using universal (OSAW) digital moisture meter.

Table 3.1 Details of greengram genotypes collected from RARS, Lam, Guntur

S. No.	Genotypes
1.	GGG-1
2.	LGG-407
3.	LGG-450
4.	LGG-460
5.	LGG-574
6.	LGG-586
7.	LGG-595
8.	LGG-607
9.	LGG-610
10.	PM-5
11.	TM-92-2
12.	WGG-42

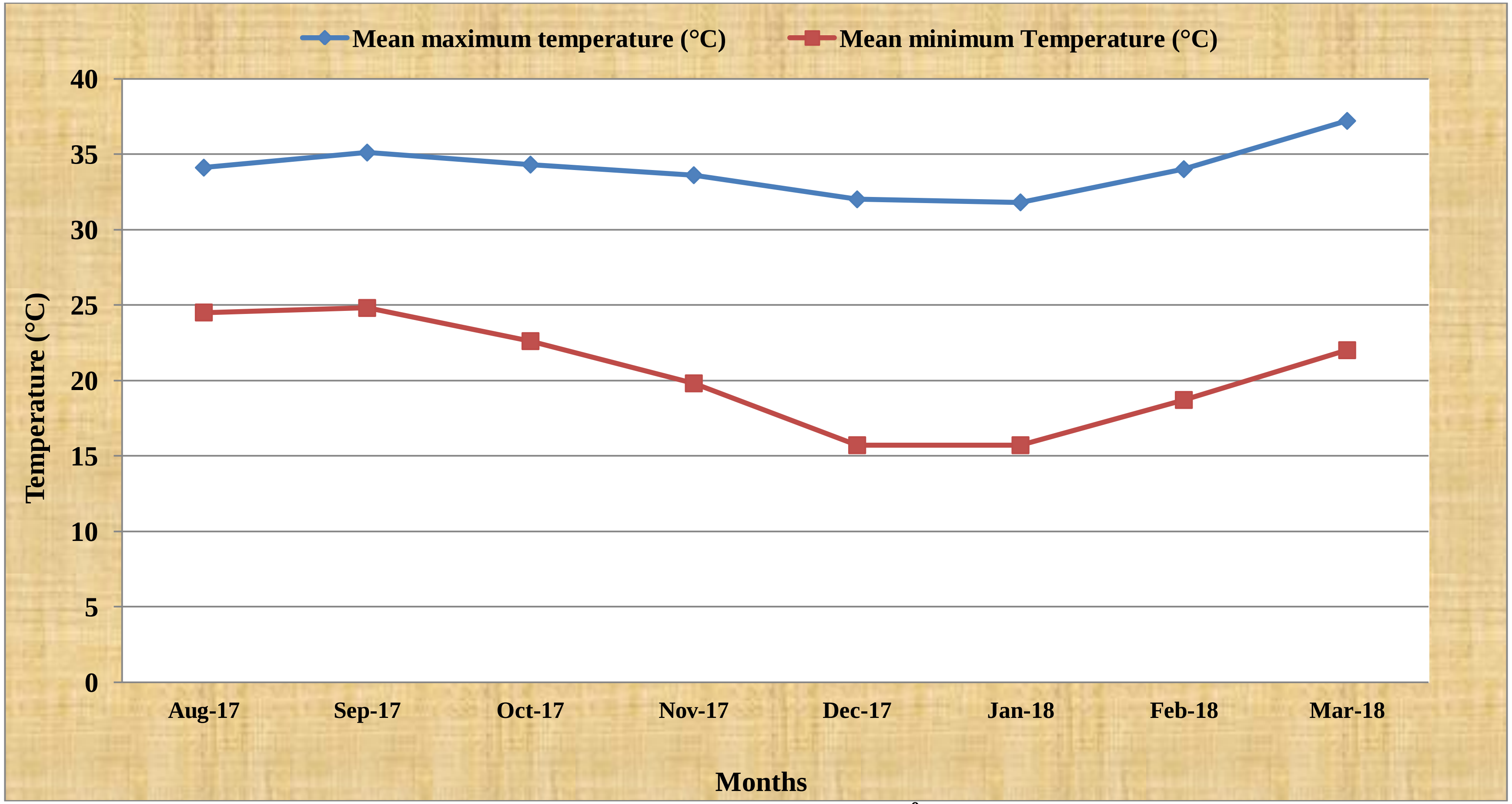


Figure 3.1 Mean maximum and minimum temperatures (^{0}C) during experimental period

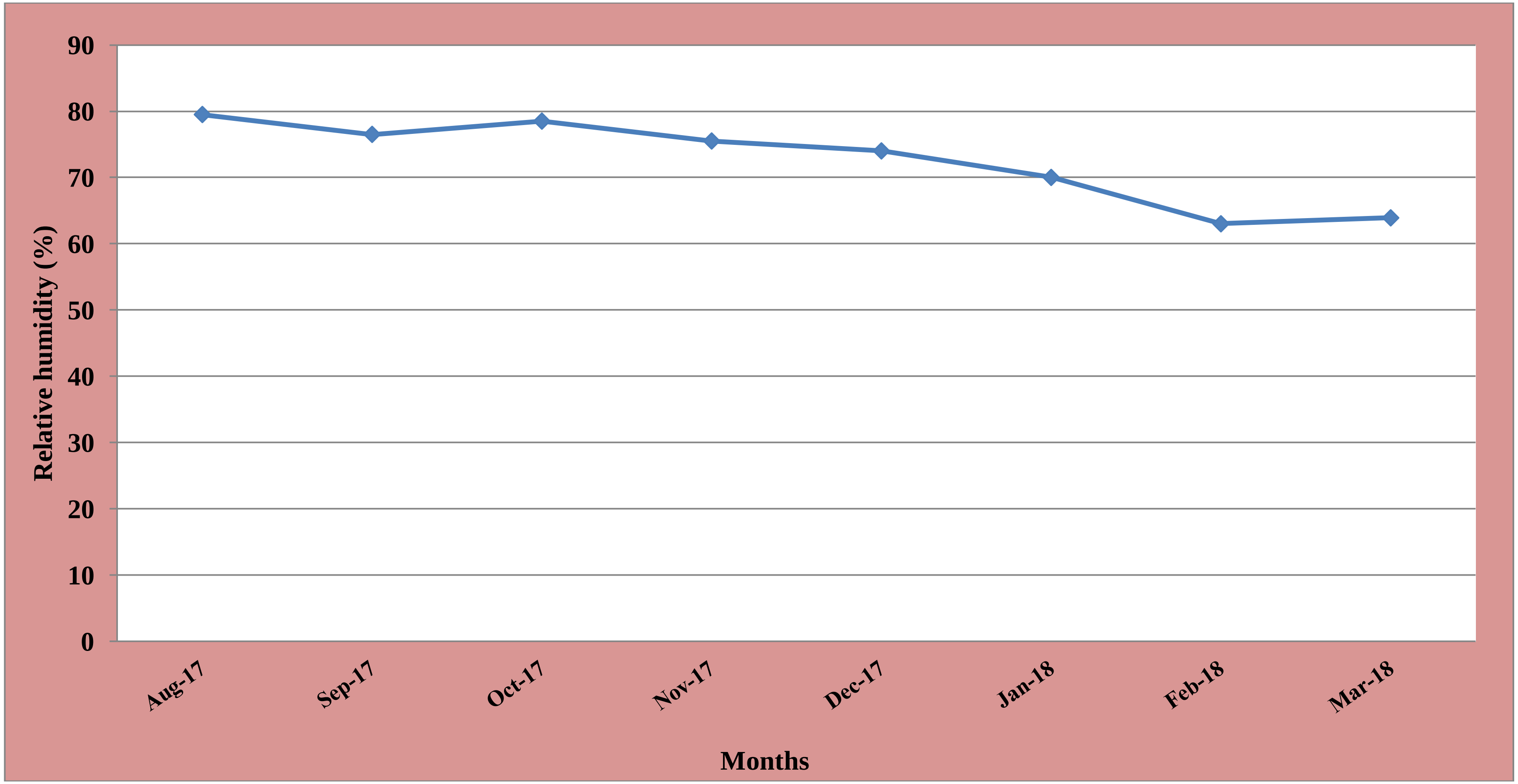


Figure 3.2 Mean relative humidity (%) during experimental period

3.1.2 Insect Culture and Maintenance

The culture of pulse beetle (*Callosobruchus chinensis*)were obtained from the stock culture at Regional Agricultural Research Station, Lam, Guntur. This culture maintained in plastic jars of one litre capacity containing greengram seed. The mouth of the jar was covered with muslin cloth and fastened tightly with the help of a rubber band. Freshly emerged insects from the culture were used for the experiment.

3.1.3 Identification of the Test Insect

The adult beetles of *C. chinensis* were identified as per the key given by Vats (1974) and Begum *et al*. (1982). The adults are brownish beetles, narrower towards the head region and broad at the posterior side measuring 2-3 mm long (Plate 3.1). The adult beetle possess two ivory spots one on each elytra. Sexing of the insect was done mainly based on antennal character. Antennae are pectinate in male and serrate in female. Abdomen is not covered by the elytra and pygidium is well exposed in case of females.

3.1.4 Collection and Preparation of Ecofriendly Materials

The plant materials *i.e.*, rhizomes of turmeric, leaves of neem, seed kernels of neem collected were shade dried and made into powder in a grinder and filtered with 60 mesh sieve. Inert dust and fly ash were procured from nearby village. Pure coconut oil and malathion were procured from nearby market. The details of treatment along with dosage are furnished in table 3.2.

Table 3.2 Details of eco-friendly material usedfor the control of *C. chinensis*ingreengram

S.No	Treatment	Dosage
1.	Turmeric powder	20 g kg^{-1} seed
2.	Neem leaf powder	25 g kg^{-1} seed
3.	Neem seed kernel powder	5 g kg^{-1} seed
4.	Coconut oil	5 ml kg^{-1} seed
5.	Inert dust	5 g kg^{-1} seed
6.	Fly ash	10 g kg^{-1} seed
7.	Malathion dust (check)	1 g kg^{-1} seed
8.	Untreated control	-

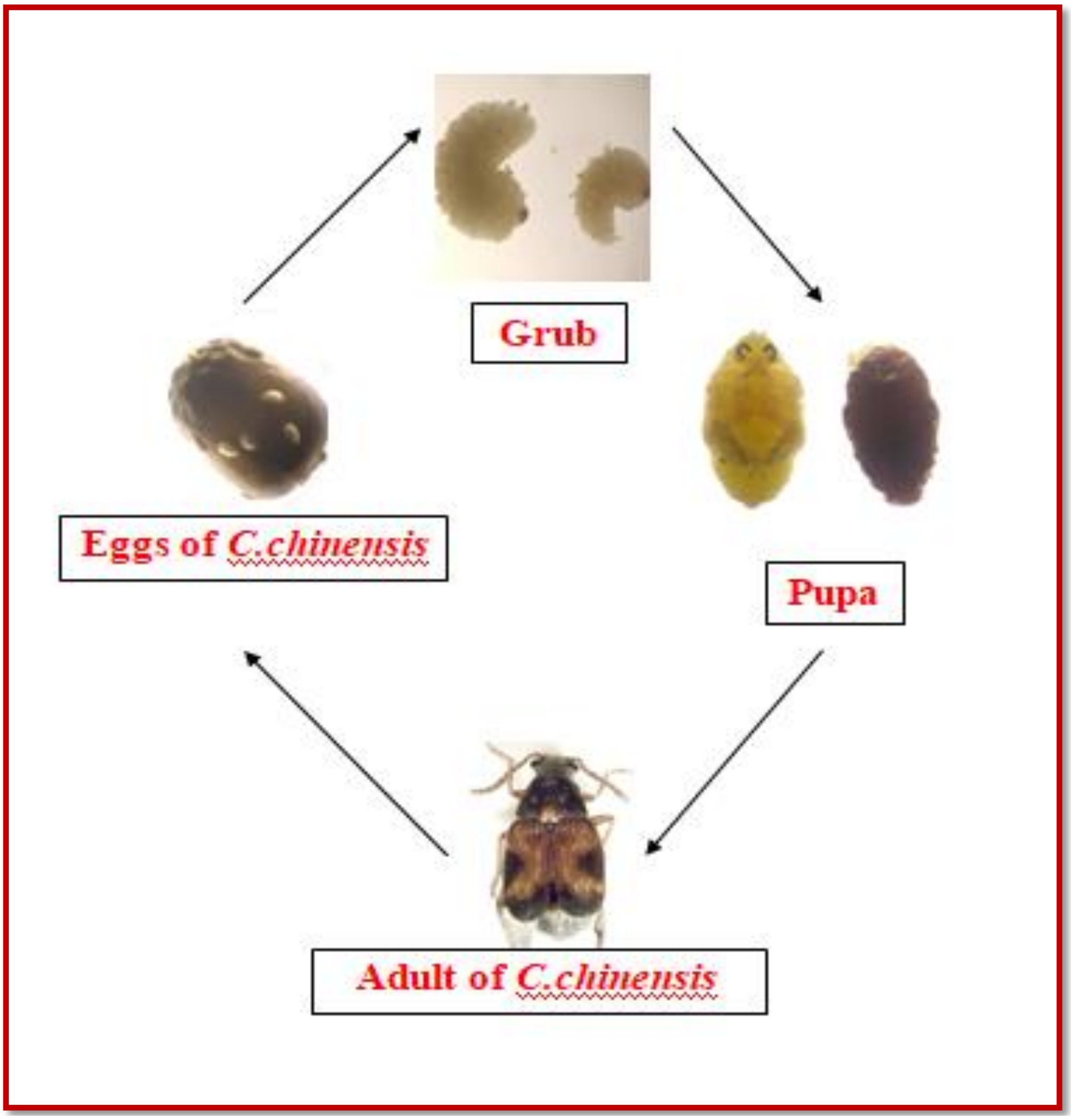


Plate 3.1. Life cycle of *Callosobruchus chinensis*

Plate 3.2. No choice test in greengram genotypes

The present study was conducted under laboratory conditions with the following experiments:

- Studies on the infestation level of pulse bruchid under no-choice artificial conditions in different greengram genotypes during seed storage
- Studies on the physico-chemical properties of seed of different greengram genotypes against pulse bruchid
- Evaluation on the effectiveness of eco-friendly material as seed protectants against pulse bruchid in greengram

3.2 STUDIES ON THE INFESTATION LEVEL OF PULSE BRUCHID UNDER NO-CHOICE ARTIFICIAL CONDITIONS IN DIFFERENT GREENGRAM GENOTYPES DURING SEED STORAGE

Under no choice test (Plate 3.2), 100 g seed of each greengram variety was taken in a plastic container into which two pairs of freshly emerged bruchids were released. After collecting the adults from stock culture, they were kept in deep freezer for few minutes in order to inactivate counting and sexing. After introducing the bruchids into each jar, the mouth of the jar was secured with perforated lids.After three days, the adults were removed and data on oviposition was recorded. The data recorded at monthly interval upto eight months of storage on various biological parameters of pulse bruchid *i.e.*,number of eggs laid, adult emergence, seed weight loss, mean development period and growth index and seed quality parameters *i.e.*,germination, seedling length, seedling vigour index, electrical conductivity of seed leachates and moisture content. The experiment was laid out in Completely Randomized Design with three replications under ambient conditions.

3.3STUDIES ON THE PHYSICO-CHEMICAL PROPERTIES OF SEED OF DIFFERENT GREENGRAM GENOTYPES AGAINST PULSE BRUCHID

The experiment was laid out in Completely Randomized Design with three replications under ambient conditions.

3.3.1 Physical Parameters

3.3.1.1 Seed Colour: Seed colour was determined by comparing colour of the seed coat with different shades of various colours by visual examination and classified as green, dark green, light green, olive green and light olive green (Plate 3.3).

3.3.1.2Seed Surface Texture: From each genotype hundred seed were selected randomly and texture was recorded by visual observation and classified as smooth, rough and wrinkled.

3.3.1.3 Seed Shape: From the same sample, observations were carried on their shape and classified as ovoid, oblong, globose and cylindrical shaped.

3.3.1.4 Seed Length and Width (mm): Ten seed were taken from the each replication at random and the seed length and width was measured with the help of the vernier calipers (Plate 3.4) and mean seed length and width was expressed in mm.

3.3.1.5 Seed Coat Hardness (%): The seed coat hardness was determined by the water absorption method and expressed as percentage increase in the seed weight. For this purpose, 20 seed were selected randomly and weighed, then soaked in 25 ml of distilled water and incubated at 25 ^{0}C for overnight. The next day, water was decanted and seed rubbed over blotters to remove the water adhering the surface and weighed again.The seed coat hardness was calculated by following formula:

$$\text{Seed coat hardness (\%)} = \frac{W_2 - W_1}{W_1} \times 100$$

Where,

W_1- Weight of seed before soaking in distilled water

W_2- Weight of seed after soaking in distilled water

3.3.1.6 100 Seed Weight (g): 100seed from each replication and treatment were chosen manually at random and their weight was recorded on precision balance (Model: DS-852G) (Plate 3.5) and weight was expressed in grams.

GGG-1

LGG-407

LGG-450

LGG-460

LGG-574

LGG-586

LGG-595

LGG-607

LGG-610

PM-5

TM-92-2

WGG-42

Plate 3.3. Greengram genotypes used in this study

Plate 3.4. Digital vernier calipers

Plate 3.5. Electronic balance

3.3.2Biochemical Parameters

The biochemical parameters *viz.*, soluble protein content, total phenol content and total soluble sugar content (Plate 3.6) in the seed of selected greengram genotypes were estimated using the following procedures.

3.3.2.1 Preparation of Oven Dried Sample: The seed samples of different genotypes were dried at 60 ^{0}C in a hot air oven for 3 days. Seed were ground by using pestle and mortar. The powdered samples were sieved through a 100 mesh screen and stored in the sealed containers at 4 ^{0}C, until analysis.

3.3.2.2 Estimation of Soluble Protein Content: Protein content in greengram seed was estimated by using bovine serum albumin as the standard method suggested by Lowry *et al*. (1951).

Reagents

1. Solution A: 20 g of anhydrous carbonate (Na_2CO_3) and 4 g of sodium hydroxide were dissolved in 1000 ml of distilled water.

2. Solution B: 1 ml of 1.35 sodium potassium tartarate ($C_4H_4KNaO_6{}^*4H_20$) and 0.1 ml of 5.5% copper sulphate ($CuSO_45H_2O$) solutions were mixed together.

3. Solution C: 50 ml solution of A was mixed with 1 ml of solution B just before use.

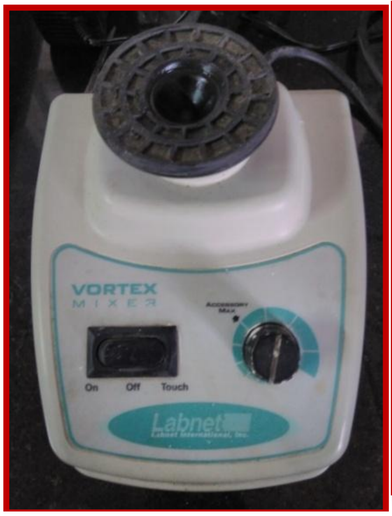
4. Folin- ciocalteau reagent (FCR): Diluted the commercial FCR (2N) with distilled water in 1:1 (v/v) ratio before use.

5. Standard bovine serum albumin (BSA) solution: A stock BSA solution was prepared containing 2mg BSA per ml working standard solution.

Sample extraction

100 mg of oven dried powdered sample was extracted in 10 ml of 0.1 M sodium phosphate buffer, pH 7.0 for one hour on a magnetic stirrer at room temperature. The extract was centrifuged at 10,000 rpm for 20 minutes and the supernatant was used for the estimation of total soluble protein content.

a. Centrifuge **b. Water bath**



c. Vortex mixer **d. Spectrophotometer**

Plate 3.6. Equipment used for biochemical analysis

Estimation

1 ml aliquot sample was taken and to this 5 ml of solution C was added and mixed well. After 10 minutes, 0.5 ml of FCR was added and mixed the content immediately on a vortex mixer. The blue colour (Plate 3.7) developed was measured at 660 nm after 30 minutes with spectrophotometer against a reagent blank.

The protein content was calculated from a standard graph prepared by using bovine serum albumin solution (20-200 g ml^{-1}). The total soluble protein content is expressed as mg per gram of oven dried sample.

3.3.2.3 Estimation of Total Phenol Content: Phenols from greengram seed were estimated using folin- ciocalteau reagent method suggested by Swain and Hillis (1959). Phenols react with phosphorus molybdic acid in folin- ciocalteau reagent in alkaline medium and produce blue coloured complex (molybdenum blue) (Plate 3.8).

Reagents

1. Folin- ciocalteau reagent: Diluted the folin- ciocalteau reagent (2N) with distilled water in 1:1 ratio before use.

2. Sodium carbonate solution: Dissolved the anhydrous sodium carbonate (35.0 g) in 100 ml of distilled water by heating on a water bath at 70-80 ^{0}C. Cool the contents for overnight and use the supernatant.

3. Standard catechol solution: A stock catechol solution was prepared containing 1 mg catechol per ml in water, this solution was diluted as 1:10 to obtain 100 µg catechol per ml working standard solution.

Sample extraction

100 mg of oven dried powdered sample was dissolved in 10 ml of warm 80 per cent ethanol for one hour on at room temperature, the extract was centrifuged at 6000 rpm for 15 minutes and supernatant was collected in a 25 ml volumetric flask. Repeated the extraction procedure three times and sample become free from phenol. Make the final volume to 25 ml with 80 % ethanol.

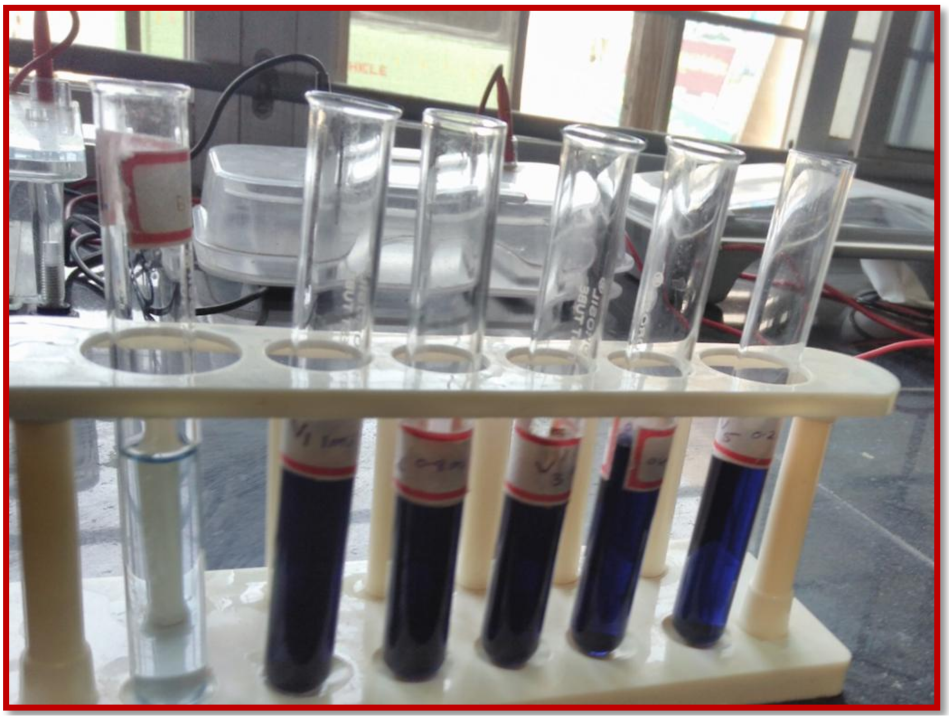


Plate 3.7. Estimation of proteins using Lowry method

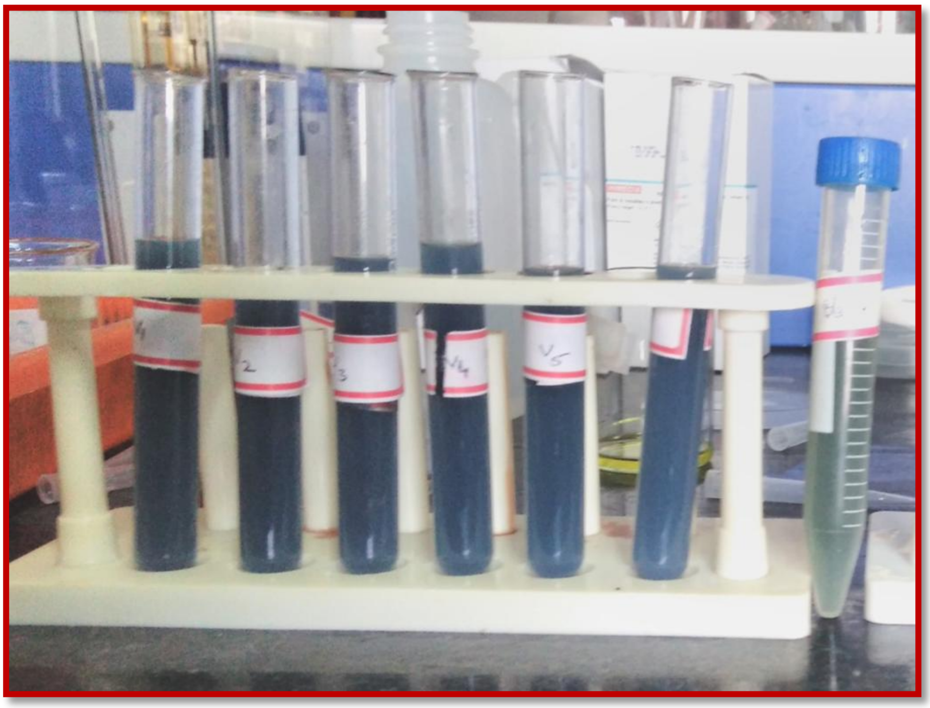


Plate 3.8. Estimation of phenols using Folin-ciocalteau reagent method

Estimation

An aliquot sample of 1 ml was diluted to 7.5 ml with distilled water and 0.5 ml of diluted FCR was added and mixed. Exactly after 3 minutes, 1ml of saturated sodium carbonate solution was added and made total volume to 10 ml with distilled water and kept in a boiling water bath for one minute and then allowed to cool and were measured at 725 nm with spectrophotometer against the reagent blank.

The phenol content was calculated from a standard graph prepared by using catechol as a standard in the range of 20-100 µg. The total phenol content was expressed as the mg per gram of oven dried sample.

3.3.2.4 Estimation of Total Soluble Sugar Content: Total soluble sugars in greengram samples may be estimated by the method suggested by Dubois *et a1*. (1956). In hot acidic medium glucose was dehydrated to hydroxymethyl furfural. This form a golden yellow colored complex (Plate 3.9) with phenol and has absorption maxima at 490 nm.

Reagents

1. **Phenol reagent:** 5 gm of redistilled phenol was dissolved in water and made up to 100 ml.

2. **Standard glucose solution:** A stock glucose solution was prepared containing 1 mg of glucose per ml in water. The solution was diluted to 1:10 to obtain 100 µg glucose per ml working standard solution.

3. Concentrated H_2SO_4.

Sample extraction

100 mg of oven dried powdered sample was dissolved in 10 ml of warm 80 per cent ethanol for one hour on at room temperature, the extract was centrifuged at 6000 rpm for 15 minutes and collected the filtrate in a 25 ml volumetric flask. Repeated the extraction procedure three times and sample become free from sugar. Make the final volume to 25 ml with 80 % ethanol.

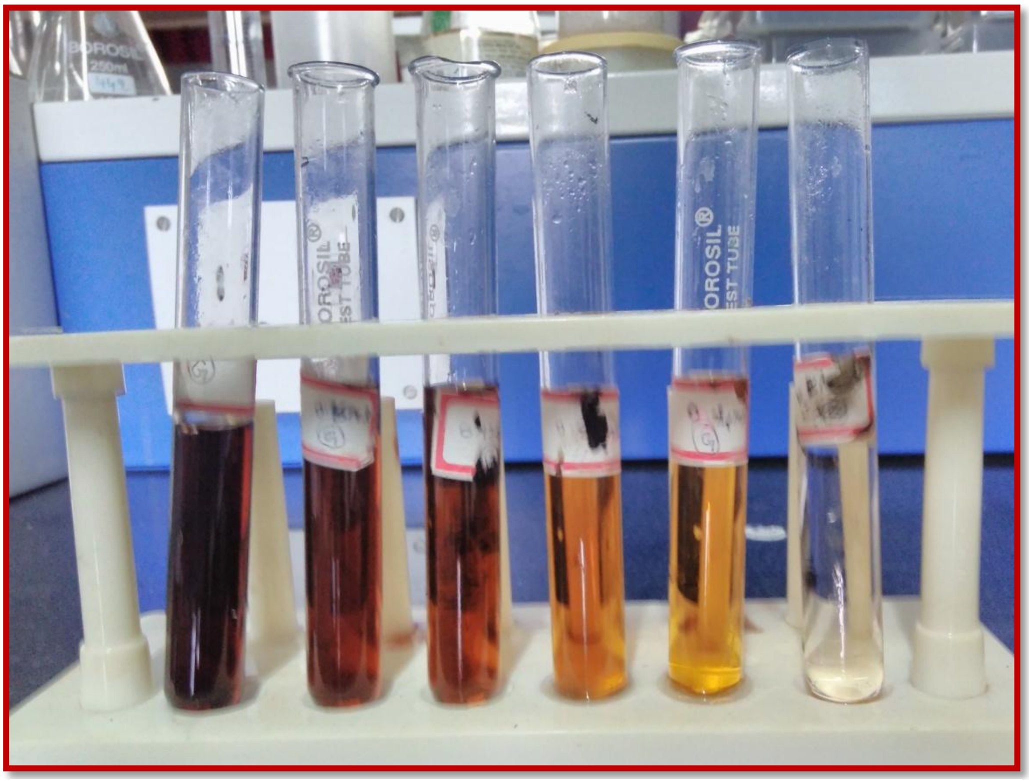


Plate 3.9. Estimation of sugars using Phenol reagent

Plate 3.10. Seed protectants used in the present study

Estimation

An aliquot of 1 ml was diluted to 10 ml with distilled water. 2 ml of 5 per cent phenol reagent and 5 ml of 98 per cent H_2SO_4 was added and incubated for 10 minutes and then placed in water bath at 30 ^{0}C for 20 minutes. The absorbance was read at 490 nm with spectrophotometer against the reagent blank.

The sugar content was calculated from a standard graph prepared by using glucose solution as a standard in the range of 20-100 µg. The total soluble sugar content is expressed as mg per gram of oven dried sample.

3.4 EVALUATION ON THE EFFECTIVENESS OF ECO-FRIENDLY MATERIAL AS SEED PROTECTANTS AGAINST PULSE BRUCHID IN GREENGRAM

Ecofriendly material *viz.,* turmeric rhizome powder, neem leaf powder, neem seed kernel powder, coconut oil, inert dust and fly ash, which have insecticidal and ovicidal properties were evaluated in the present study for their effectiveness in controlling bruchid infestation in greengram (Plate 3.10). Malathion dust was used as chemical check and one untreated control was used for comparision.

For each treatment, one kg of greengram seed was taken into a small cloth bag and was treated with the test materials at specified doses and were stored under normal storage conditions in seed godown of RARS, Lam. Two pairs of freshly emerged adults were released into each cloth bag. The data recorded at monthly interval upto eight months of storage on various biological parameters of pulse bruchid *i.e.,*number of eggs laid, adult emergence, seed weight loss and adult mortality and seed quality parameters *i.e.,*germination, seedling length, seedling vigour index, electrical conductivity of seed leachates and moisture content. The experiment was laid out in Completely Randomized Design with three replications under ambient conditions.

3.5OBSERVATIONS RECORDED

Observations were taken from each genotype at monthly interval upto eight months of storage for the following parameters.

3.5.1 Biological Parameters

3.5.1.1 Number of Eggs: After three days, the insects were removed and the number of eggs laid on 100 seeds was counted with the help of magnifying glass and the mean number of eggs laid was calculated.

3.5.1.2 Adult Emergence (%): Adult emergence (%) was calculated using the following formula suggested by Howe (1971).

$$\text{Adult emergence (\%)} = \frac{\text{Number of adults emerged}}{\text{Number of eggs laid}} \times 100$$

3.5.1.3 Seed Weight Loss (%): The number and weight of damaged and undamaged grains of composite sample of 100 seed were taken from each replication in each genotype at final observation. Percentage weight loss was calculated by using the count and weight method by using the formula (Adams, 1976).

$$\text{Seed weight loss (\%)} = \frac{(Wu \times Nd) - (Wd \times Nu)}{Wu \times (Nd + Nu)} \times 100$$

Where, Wu = Weight of undamaged grains

Wd = Weight of damaged grains

Nu = Number of undamaged grains

Nd = Number of damaged grains

3.5.1.4 Mean Development Period (days): Mean development period (MDP) is the time taken in days for 50 per cent of the adults to emerge. It was estimated using the following formula given by Howe (1971).

$$\text{Mean Development period (days)} = \frac{D_1A_1 + D_2A_2 + D_3A_3 + \ldots\ldots D_nA_n}{\text{Total number of adults emerged}} \text{ X } 100$$

Where,

D_1– Day at which the adults started emerging (First day)

A_1– Number of adults emerged on the day D_1

A_n– Number of adults emerged on the day D_n

3.5.1.5 Growth Index of Pulse Bruchid: Growth Index (GI) was calculated using the following formula (Jackai and Singh, 1988).

$$\text{Growth Index of pulse bruchid} = \frac{\text{Adult emergence (\%)}}{\text{Mean development period}}$$

The greengram genotypes used in the present study were categorized based on the growth index as per the following classification given by Mensah (1986).

Resistant	: 0 – 1.60
Moderately resistant	: 1.60 – 1.65
Moderately susceptible	: 1.65 – 1.70
Susceptible	: 1.70 – 1.75
Highly susceptible	: > 1.75

3.5.1.6 Adult Mortality (%): The adult mortality was calculated on the basis of the number of dead insects. Insects showing movement of legs and antennae were considered as alive. The adult mortality with respect to control was determined by using the following formula:

$$\text{Adult mortality (\%)} = \frac{\text{Adult emergence in control} - \text{Adult emergence in treatment}}{\text{Adult emergence in control}} \times 100$$

3.5.2 Seed Quality Parameters

3.5.2.1 Moisture Content (%): The moisture content of greengram seed was determined by universal (OSAW) digital moisture meter (Plate 3.11). The principle involved in moisture meter is that wet grains are good conductors while dry grains are low conductors of electricity. So, the moisture content is directly proportional to the electrical conductivity of the seed. It consists of a compression unit to compress the sample to pre-determined thickness. The thickness setting is very easily read on a vertical and circular scale.

The seed material from each treatment in three replications was collected in a test cup and was compressed to evaluate the moisture content. Then push the switch separately till the reading appeared on the display. The computer version of digital moisture meter automatically compensated for temperature corrections.

3.5.2.2 Germiation (%): 100 seed of each treatment were kept 'between the paper' (BP) towels soaked with distilled water and kept in plastic trays. All the treatments were replicated thrice. On the 8th day after start of the test, the paper towels were opened to recorded the germination (Plate 3.12). Finally, the germination per cent was calculated using the following equation:

$$\text{Germination (\%)} = \frac{\text{No. of germinated seed}}{\text{Total no. of seed}} \times 100$$

Plate 3.11. OSAW universal moisture meter

Plate 3.12. Germination test by rolled paper towel method

3.5.2.3 Seedling Length (cm): Ten normal seedlings were taken from the each replication at random on the 8^{th} day and the seedling length was measured from tip of the primary leaf to the tip of the primary root with the help of the scale and mean seedling length was expressed in centimeters.

3.5.2.4 Seedling Vigour Index: The seedling vigour index (SVI) was calculated by following formula suggested by Abdul-Baki and Anderson (1973)

Seedling vigour index = Germination (%) x Seedling length (cm).

3.5.2.5 Electrical Conductivity of Seed Leachates (dSm^{-1}): Twenty five randomly selected seed were soaked in 25 ml of deionized water for 24 h at room temperature. The seed steep water was decanted and referred to as seed leachate. The electrical conductivity of the seed leachate was measured in a digital conductivity meter (Model: Conductivity TDS meter-307) (Plate 3.13) with a cell constant of one and expressed as dSm^{-1}.

3.6 STATISTICAL ANALYSIS

The data of storability studies were subjected to square root and angular transformation wherever necessary and analyzed by adopting Completely Randomized Design as suggested by Panse and Sukhatme (1985). Data obtained were subjected to analysis of variance (ANOVA) procedure using OP STAT software. The treatment means were compared using Duncan’s multiple range test ($P<0.05$) using SPSS software (version 6.0) at 1 % and 5 % level of significance.

Simple correlation coefficients and multiple regression analysis were worked out between physico-chemical parameters and biological parameters of the test insect of greengram genotypes as suggested by Steel and Torrie (1980).

Chapter – IV

Results and Discussion

Chapter IV

RESULTS AND DISCUSSION

Studies on the influence of seed physico-chemical properties on bruchid (*Callosobruchus chinensis* L.) and its management in greengram were carried out under laboratory conditions in Regional AgriculturalResearch Station (RARS), Lam, Guntur andDepartment of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur. The results obtained through these investigations are presented and discussed below under the light of available literature.

4.1 STUDIES ON THE INFESTATION LEVEL OF PULSE BRUCHID UNDER NO-CHOICE ARTIFICIAL CONDITIONS IN DIFFERENT GREENGRAM GENOTYPES DURING SEED STORAGE

The twelve greengram genotypes collected from the Regional Agricultural Research Station, Lam, Guntur were tested for their resistance to *C. chinensis* under laboratory conditions in Department of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur for a period of eight months from August, 2017 to March, 2018 under ambient conditions. The data recorded on biological parameters of the pulse bruchid and seed quality parameters were statistically analysed and discussed here under:

4.1.1 Biological Parameters

The data recorded at monthly interval upto eight months of storage on various biological parameters of pulse bruchid *i.e.,*number of eggs laid, adult emergence, seed weight loss, mean development period and growth index were statistically analysed and the results are discussed below:

4.1.1.1 Number of Eggs/ 100 seed: The data on number of eggs laid by pulse bruchid is presented in Table 4.1 and Fig. 4.1. The egg count significantly differed among the genotypes throughout the storage period *i.e.,* at different months. The egg laying by pulse bruchid after artificial infestation was initially low but gradually increased with increase in storage period. The mean number of eggs varied widely from first month (6.69 number/ 100 seed) to eighth month of storage (92.19 number/ 100 seed).

During the first month, the number of eggs varied from 1.67 to 11.00/ 100 seed among the different genotypes. The number of eggs was significantly low in the genotype, PM-5 (1.67 number/ 100 seed) followed by GGG-1 (2.33 number/ 100 seed), LGG-607 (3.00 number/ 100 seed) and LGG-610 (4.13 number/ 100 seed) which were significantly superior over the other genotypes. Almost similar trend was observed during the subsequent months of storage with significant differences among the genotypes (Table 4.1).

At eight months after storage also, PM-5 found significantly superior with less number of eggs (36.67 number/ 100 seed) over all the other genotypes. The next best genotype is LGG-610 with 53.67 number/ 100 seed. The highest number of eggs was found on WGG-42 (132.00 number/ 100 seed) indicating that the genotype was mostly preferred by pulse bruchid for oviposition (Table 4.1).

The pooled data over eight months showed that the greengram genotype, PM-5 was the least preferred variety by pulse bruchid which recorded significantly lowest number of eggs (14.00 number/ 100 seed). The genotype, WGG-42 was found as a highly preferred host for egg lying by pulse bruchid with significantly highest number of eggs (73.17 number/ 100 seed) (Table 4.1).

Oviposition is a paramount behavior exhibited by an insect for continuation of its race and establishment of their population. The ovipositional preference of bruchid seems to be governed by several biotic and ecological factors. There was an appreciable variation in ovipositional preference on different accessions which could be attributed to physico-chemical properties of seed. The results are in agreement with the findings of Wadnerkar *et al.* (1978) also observed differential response of oviposition by bruchid in different varieties of pigeonpea. Salunkhe and Jadhav (1982) revealed that variety Sel-436 was the least preferred (1.00 egg/ 50 g) for oviposition while the kabuli gram variety, L-550 was the most preferred (825 eggs/ 50 g). Khokhar and Singh (1987) who reported that the number of eggs laid by the bruchid on pigeonpea varieties varied from 34.66/ 100 seed to as high as 238.00/ 100 seed and stated that ICPL-143, ICPL-148 and H-79-4 were least preferred by the bruchid. Singh and Pandey (2001) noted that among 20 pea varieties, Rachna was the least preferable for egg laying by the bruchids. Arpitha and Sagar (2011) stated that Yellow local (24.00 eggs/ 100 seed of *C. chinensis*) and Green local (25.00/ 100 seed eggs of *C. chinensis*) varieties of pea were less preferred

Table 4.1Egg laying by pulse bruchid on different greengram genotypes in storage after artificial infestation

Genotypes	Number of eggs/ 100 seeds								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
GGG-1	2.33 (1.82)^{f}	4.67 (2.38)^{g}	7.33 (2.89)^{f}	14.33 (3.92)^{h}	25.67 (5.16)^{h}	33.67 (5.88)^{g}	42.67 (6.61)^{g}	69.00 (8.36)^{f}	**24.96 (5.09)^{g}**
LGG-407	8.33 (3.05)^{b}	13.67 (3.83)^{c}	17.67 (4.32)^{c}	38.33 (6.27)^{c}	54.33 (7.43)^{d}	74.00 (8.66)^{c}	93.67 (9.73)^{c}	118.67 (10.94)^{c}	**52.33 (7.30)^{c}**
LGG-450	7.67 (2.94)^{b}	12.33 (3.65)^{cd}	16.67 (4.20)^{c}	34.33 (5.94)^{d}	58.00 (7.68)^{c}	83.00 (9.16)^{b}	99.33 (10.02)^{b}	123.33 (11.15)^{bc}	**54.33 (7.44)^{c}**
LGG-460	6.33 (2.71)^{c}	9.67 (3.27)^{e}	11.33 (3.51)^{e}	24.67 (5.06)^{f}	39.67 (6.38)^{f}	50.67 (7.18)^{e}	72.00 (8.54)^{e}	86.00 (9.33)^{e}	**37.54 (6.21)^{e}**
LGG-574	9.67 (3.27)^{a}	11.67 (3.56)^{d}	14.33 (3.91)^{d}	29.00 (5.48)^{e}	49.67 (7.12)^{e}	60.00 (7.81)^{d}	80.67 (9.03)^{d}	99.00 (10.00)^{d}	**44.25 (6.73)^{d}**
LGG-586	10.33 (3.37)^{a}	16.67 (4.20)^{b}	21.67 (4.76)^{b}	52.67 (7.32)^{b}	76.33 (8.79)^{b}	84.00 (9.22)^{b}	103.33 (10.21)^{b}	130.00 (11.45)^{ab}	**61.88 (7.93)^{b}**
LGG-595	5.33 (2.51)^{d}	5.67 (2.58)^{f}	6.00 (2.65)^{g}	21.00 (4.69)^{g}	31.67 (5.71)^{g}	43.67 (6.68)^{f}	59.00 (7.75)^{f}	82.00 (9.11)^{e}	**31.79 (5.73)^{f}**
LGG-607	3.00 (2.00)^{f}	4.67 (2.38)^{g}	8.00 (3.00)^{f}	22.67 (4.86)^{fg}	30.67 (5.63)^{g}	42.33 (6.58)^{f}	57.67 (7.66)^{f}	80.33 (9.02)^{e}	**31.17 (5.65)^{f}**
LGG-610	4.33 (2.31)^{e}	4.67 (2.38)^{g}	5.33 (2.51)^{g}	13.33 (3.78)^{h}	21.33 (4.72)^{i}	31.00 (5.66)^{g}	41.33 (6.51)^{g}	53.67 (7.39)^{g}	**21.88 (4.78)^{g}**
PM-5	1.67 (1.63)^{g}	2.67 (1.91)^{h}	3.00 (2.00)^{h}	7.33 (2.88)^{i}	13.33 (3.79)^{j}	20.33 (4.62)^{h}	27.00 (5.28)^{h}	36.67 (6.12)^{h}	**14.00 (3.87)^{h}**
TM-92-2	10.33 (3.37)^{a}	13.33 (3.79)^{c}	16.67 (4.20)^{c}	31.00 (5.66)^{e}	47.00 (6.93)^{e}	59.00 (7.75)^{d}	75.33 (8.74)^{e}	95.67 (9.83)^{d}	**43.54 (6.67)^{d}**
WGG-42	11.00 (3.46)^{a}	21.33 (4.73)^{a}	31.33 (5.69)^{a}	67.67 (8.29)^{a}	83.33 (9.18)^{a}	110.00 (10.54)^{a}	128.67 (11.39)^{a}	132.00 (11.53)^{a}	**73.17 (8.61)^{a}**
Mean	6.69 (2.70)	10.08 (3.22)	13.28 (3.64)	29.69 (5.35)	44.25 (6.54)	57.64 (7.48)	73.39 (8.46)	92.19 (9.52)	**40.90 (6.33)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.06	0.06	0.07	0.07	0.08	0.10	0.10	0.12	**0.11**
C.D. (5%)	0.18	0.17	0.19	0.22	0.24	0.30	0.29	0.35	**0.31**
C.V. (%)	3.96	3.14	3.15	2.43	2.18	2.38	2.00	2.19	**2.93**

MAR: Months after release

Figures in parenthesis are square root transformed values

Means in the same column showing similar alphabets are not significantly different

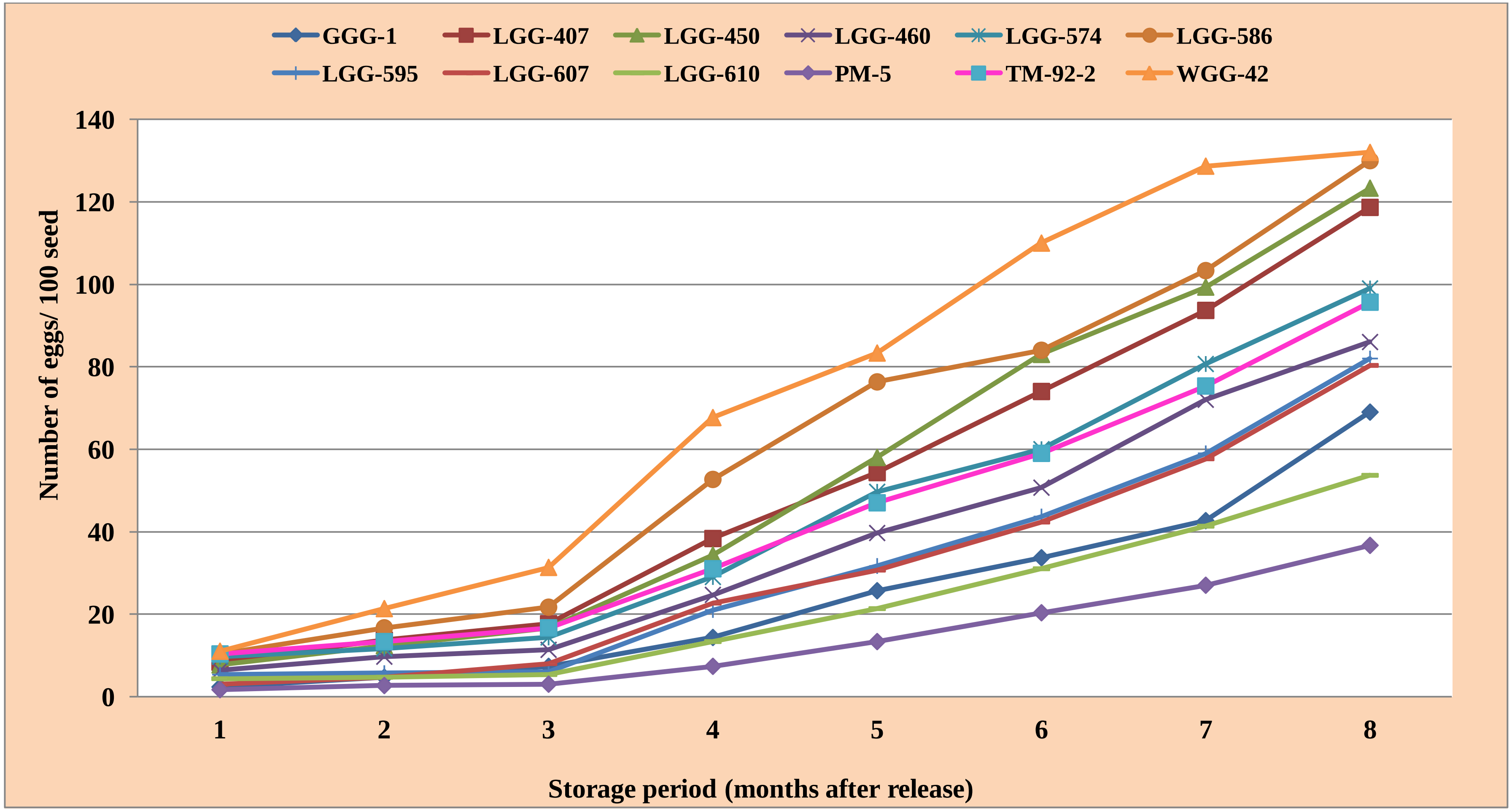


Figure 4.1. Egg laying by pulse bruchid on different greengram genotypes in storage after artificial infestation

for egg laying by the pulse beetle adults. On the other hand, Siddiqua *et al.* (2015) reported that the oviposition by *C. chinensis* had no significant difference on candidate varieties in chickpea.

4.1.1.2 Adult Emergence (%): The adult emergence of pulse bruchid was initially low (Plate 4.1 and Plate 4.3) but gradually increased with the duration of storage with significant differences among the genotypes. The mean adult emergence varied widely from first month (38.67 %) to eighth month of storage (52.64 %) (Table 4.2 and Fig. 4.2) among the different genotypes.

During the first month, the adult emergence varied from 0.00 to 53.03 % among the different genotypes. The adult emergence was nil in the genotype, PM-5 (0.00 %), while the adult emergence was significantly high from WGG-42 (53.03 %). The same trend was observed during the subsequent months of storage with significant differences among the genotypes regarding adult emergence (Table 4.2).

At eight months after storage, the adult emergence from greengram genotypes ranged from 23.07 to 73.00 %. Significantly lowest adult emergence (23.07 %) was recorded from PM-5 (Plate 4.2) which might be due to less oviposition by the bruchids. The next best genotypes were LGG-610 and LGG-607 which recorded 37.23 % and 38.20 % adult emergence, respectively and were found at par with each other. The highest adult emergence was recorded from WGG-42 (73.00 %) (Plate 4.4), hence proved as most preferred genotype for adult development. LGG-574, TM-92-2 and LGG-460 recorded adult emergence between 56.16 % to 57.56 % and were on par with each other (Table 4.2).

The pooled data over eight months indicated significant differences among the genotypes in adult emergence of pulse bruchid. PM-5 was the least preferred genotype by pulse bruchid which recorded significantly lowest adult emergence (17.44 %). The other genotype which recorded less adult emergence was LGG 610 (31.34 %) over all the other genotypes. The genotype, WGG-42 was found to be highly preferred genotype by pulse bruchid with highest adult emergence (63.20 %) among the different genotypes (Table 4.2).

The present study is in close agreement with the reports of Obadofin (2014) who stated that the adult emergence varied significantly among the cowpea varieties. Radha and Susheela (2014a) also reported that there were significant differences in the percentage of adults emerged between different pulses.

Table 4.2 Adult emergence (%) of pulse bruchid on different greengram genotypes in storage after artificial infestation

Genotypes	Adult emergence (%)								
	1 MAR	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
GGG-1	33.33 (34.99)^{e}	35.67 (36.65)^{f}	36.77 (37.31)^{f}	38.41 (38.28)^{f}	40.76 (39.66)^{f}	43.54 (41.27)^{f}	45.80 (42.57)^{e}	47.54 (43.58)^{e}	**40.23 (39.35)^{e}**
LGG-407	48.15 (43.92)^{ab}	50.00 (44.98)^{bc}	53.19 (46.81)^{b}	54.29 (47.44)^{c}	58.06 (49.62)^{abc}	58.84 (50.07)^{bc}	60.69 (51.15)^{b}	62.18 (52.03)^{b}	**55.67 (48.24)^{b}**
LGG-450	49.00 (44.41)^{ab}	51.60 (45.90)^{b}	52.33 (46.32)^{bc}	54.64 (47.64)^{bc}	56.10 (48.49)^{bcd}	57.99 (49.58)^{c}	60.78 (51.21)^{b}	63.94 (53.08)^{b}	**55.80 (48.31)^{b}**
LGG-460	42.62 (40.74)^{cd}	45.44 (42.37)^{d}	46.67 (43.06)^{d}	49.52 (44.71)^{d}	52.79 (46.60)^{cde}	53.97 (47.26)^{d}	55.21 (47.97)^{c}	57.56 (49.33)^{c}	**50.47 (45.25)^{c}**
LGG-574	46.15 (42.77)^{bc}	47.71 (43.67)^{cd}	47.83 (43.74)^{d}	50.95 (45.53)^{d}	52.22 (46.26)^{de}	52.90 (46.64)^{de}	54.34 (47.47)^{c}	56.16 (48.52)^{c}	**51.03 (45.57)^{c}**
LGG-586	50.00 (44.98)^{ab}	52.01 (46.13)^{b}	54.07 (47.31)^{b}	57.02 (49.02)^{b}	58.49 (49.89)^{ab}	61.94 (51.89)^{b}	62.98 (52.50)^{b}	64.61 (53.48)^{b}	**57.64 (49.38)^{b}**
LGG-595	40.00 (39.22)^{d}	40.50 (39.51)^{e}	42.00 (40.38)^{e}	43.33 (41.15)^{e}	49.19 (44.52)^{e}	50.00 (44.98)^{e}	50.86 (45.48)^{d}	51.53 (45.86)^{d}	**45.93 (42.64)^{d}**
LGG-607	30.56 (33.50)^{e}	31.33 (34.03)^{g}	33.33 (35.25)^{g}	33.78 (35.52)^{g}	34.67 (36.06)^{g}	36.42 (37.10)^{g}	37.60 (37.80)^{f}	38.20 (38.16)^{f}	**34.49 (35.95)^{f}**
LGG-610	26.00 (30.64)^{f}	26.67 (31.08)^{h}	28.56 (32.29)^{h}	30.00 (33.20)^{h}	32.70 (34.83)^{g}	33.71 (35.48)^{g}	35.85 (36.77)^{f}	37.23 (37.56)^{f}	**31.34 (34.03)^{g}**
PM-5	0.00 (0.00)^{g}	16.01 (23.58)^{i}	18.01 (25.10)^{i}	18.67 (25.58)^{i}	19.44 (26.15)^{h}	21.36 (27.41)^{h}	22.96 (28.61)^{g}	23.07 (28.69)^{g}	**17.44 (24.67)^{h}**
TM-92-2	45.15 (42.19)^{bc}	46.27 (42.84)^{d}	49.38 (44.63)^{cd}	50.40 (45.21)^{d}	53.04 (46.72)^{bcde}	54.36 (47.48)^{d}	55.22 (47.98)^{c}	56.63 (48.79)^{c}	**51.31 (45.73)^{c}**
WGG-42	53.03 (46.72)^{a}	56.77 (48.88)^{a}	61.73 (51.77)^{a}	62.77 (52.38)^{a}	63.11 (52.59)^{a}	66.07 (54.35)^{a}	69.14 (56.23)^{a}	73.00 (58.67)^{a}	**63.20 (52.64)^{a}**
Mean	38.67 (37.01)	41.67 (39.97)	43.66 (41.16)	45.32 (42.14)	47.55 (43.45)	49.26 (44.46)	50.95 (45.48)	52.64 (46.48)	**46.15 (42.65)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.89	0.56	0.61	0.49	1.00	0.67	0.56	0.58	**0.65**
C.D. (5%)	2.61	1.65	1.79	1.43	2.92	1.96	1.64	1.70	**1.89**
C.V. (%)	4.18	2.45	2.59	2.02	3.99	2.62	2.14	2.17	**2.63**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different

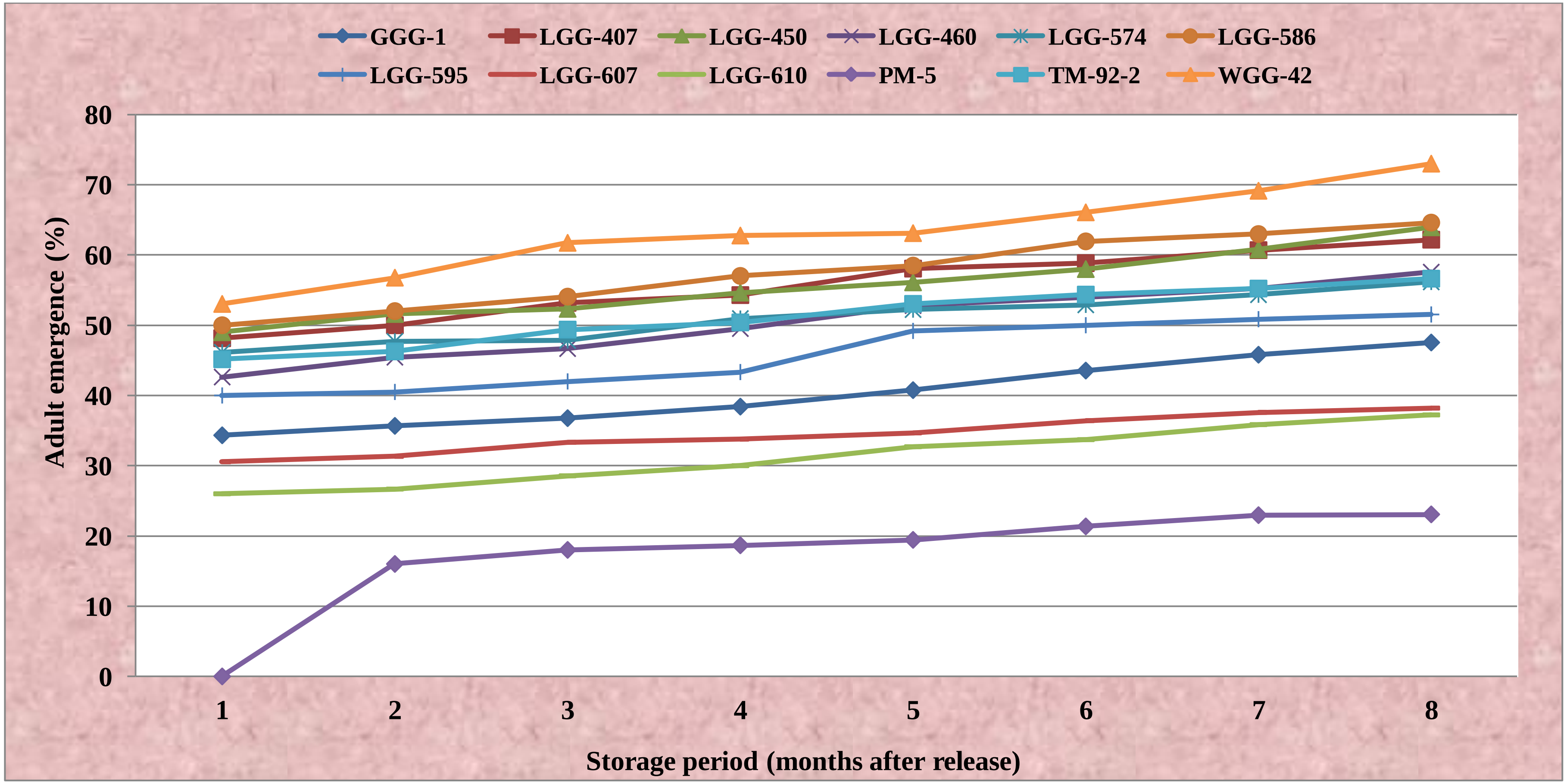


Figure 4.2. Adult emergence (%) of pulse bruchid on different greengram genotypes in storage after artificial infestation

Plate 4.1. PM-5 seed before artificial infestation

Plate 4.2 PM-5 seed after eight months of infestation

Plate 4.3. WGG-42 seed before artificial infestation

Plate 4.4. WGG-42 seed after eight months of infestation

The greengram genotype PM-5 recorded low adult emergence which might be due to very low egg laying on that genotype indicating its resistance to pulse beetle. These results are in agreement with the findings of Talekar and Lin (1992) in mungbean, Chandel *et al.* (2012) in redgram, Prasad *et al.* (2013) in dolichos bean and Siddiqa *et al.* (2015) in chickpea who attributed resistance for bruchid infestation to low adult emergence.

4.1.1.3 Weight Loss of Seed (%): The seed weight loss was initially low but gradually increased with increase in period of storage among all the genotypes (Table 4.3 and Fig. 4.3). The mean weight loss ranged from 1.33 % during first month to 27.10 % during eighth month of storage which might be due to relative increase in the population of insects. There were significant differences in seed weight loss among the genotypes irrespective of storage period.

During the first month, the weight loss varied from 0.00 to 2.90 % among the different genotypes. The weight loss was nil in the genotype, PM-5 (0.00 %). The weight loss was significantly high in WGG-42 (2.90 %). Almost similar trend was observed during the subsequent months of storage with significant differences among the genotypes (Table 4.3).

After eight months of storage, significantly lowest (2.24 %) weight loss in seed was recorded in PM-5 followed by LGG-610 with 6.91 %. The next best genotypes were LGG-607 and GGG-1 which recorded 12.90 and 13.07 per cent weight loss, respectively and were found at par with each other. The highest weight loss was recorded in WGG-42 (58.51 %) which can be attributed to highest egg laying and adult emergence (Table 4.3).

The pooled data showed that the genotype, PM-5 recorded significantly lowest weight loss (0.98 %), followed by LGG 610 (3.27 %) and hence considered as least preferred varieties over all the other genotypes studied. The genotype, WGG-42 recorded highest weight loss (29.21 %) and was categorized as highly preferred genotype by pulse bruchid among all the genotypes (Table 4.3).

The weight loss of seed is due to internal feeding habit of pulse bruchid which might cause damage to the major portion of the cotyledon, consequently leading to reduction in weight. The maggots, just after hatching bored into the seed and internal feeding is reflected as loss in seed weight (Gujar and Yadav, 1978).

Table 4.3 Weight loss (%) of seed in different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Weight loss (%)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
GGG-1	0.31 (3.17)^{h}	1.12 (6.05)^{f}	1.35 (6.65)^{f}	5.32 (13.33)^{g}	6.88 (15.20)^{e}	8.84 (17.29)^{g}	11.23 (19.57)^{e}	13.07 (21.18)^{g}	**6.01 (14.18)^{f}**
LGG-407	1.93 (7.98)^{c}	3.43 (10.66)^{c}	6.00 (14.17)^{c}	14.30 (22.20)^{c}	16.37 (23.86)^{c}	26.07 (30.69)^{c}	41.45 (40.06)^{b}	49.61 (44.76)^{c}	**19.89 (26.48)^{c}**
LGG-450	1.50 (7.02)^{d}	2.19 (8.49)^{d}	4.43 (12.14)^{d}	12.69 (20.85)^{d}	15.40 (23.10)^{c}	24.36 (29.56)^{d}	36.02 (36.87)^{c}	44.67 (41.92)^{d}	**17.66 (24.84)^{d}**
LGG-460	1.00 (5.70)^{f}	1.22 (6.31)^{ef}	2.80 (9.60)^{e}	8.25 (16.68)^{f}	9.71 (18.14)^{d}	13.71 (21.72)^{f}	18.74 (25.64)^{d}	22.38 (28.22)^{e}	**9.73 (18.16)^{e}**
LGG-574	1.56 (7.16)^{d}	1.60 (7.27)^{e}	2.77 (9.56)^{e}	7.92 (16.32)^{f}	10.45 (18.85)^{d}	14.81 (22.63)^{e}	18.57 (25.51)^{d}	22.88 (28.57)^{e}	**10.07 (18.49)^{e}**
LGG-586	2.33 (8.77)^{b}	4.77 (12.61)^{b}	7.48 (15.86)^{b}	18.18 (25.22)^{b}	23.39 (28.91)^{b}	32.24 (34.58)^{b}	42.37 (40.59)^{b}	52.95 (46.67)^{b}	**22.96 (28.62)^{b}**
LGG-595	0.31 (3.17)^{h}	0.74 (4.89)^{g}	0.85 (5.25)^{g}	3.93 (11.41)^{h}	7.29 (15.65)^{e}	9.63 (18.07)^{g}	12.46 (20.66)^{e}	15.11 (22.86)^{f}	**6.29 (14.52)^{f}**
LGG-607	1.24 (6.39)^{e}	1.26 (6.44)^{ef}	2.62 (9.30)^{e}	5.84 (13.98)^{g}	5.92 (14.07)^{f}	7.40 (15.78)^{h}	9.20 (17.65)^{f}	12.90 (21.04)^{g}	**5.80 (13.93)^{f}**
LGG-610	0.43 (3.77)^{g}	1.27 (6.46)^{ef}	1.51 (7.03)^{f}	3.61 (10.95)^{h}	3.75 (11.14)^{g}	3.76 (11.17)^{i}	4.88 (12.69)^{g}	6.91 (15.23)^{h}	**3.27 (10.40)^{g}**
PM-5	0.00 (0.00)^{i}	0.42 (3.68)^{h}	0.72 (4.86)^{g}	0.82 (5.19)^{i}	1.07 (5.80)^{h}	1.23 (6.33)^{j}	1.31 (6.50)^{h}	2.24 (8.58)^{i}	**0.98 (5.65)^{h}**
TM-92-2	2.46 (9.02)^{b}	2.49 (9.04)^{d}	4.95 (12.85)^{d}	9.98 (18.40)^{e}	10.13 (18.55)^{d}	13.02 (21.14)^{f}	18.55 (25.50)^{d}	23.98 (29.31)^{e}	**10.69 (19.03)^{e}**
WGG-42	2.90 (9.79)^{a}	5.94 (14.10)^{a}	9.79 (18.23)^{a}	23.64 (29.08)^{a}	30.72 (33.64)^{a}	47.96 (43.81)^{a}	54.22 (47.40)^{a}	58.51 (49.88)^{a}	**29.21 (32.70)^{a}**
Mean	1.33 (5.99)	2.21 (8.00)	3.77 (10.46)	9.54 (16.97)	11.76 (18.91)	16.92 (22.73)	22.42 (26.55)	27.10 (29.85)	**11.88 (18.92)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.19	0.36	0.32	0.32	0.33	0.27	0.44	0.41	**0.35**
C.D. (5%)	0.55	1.04	0.92	0.94	0.97	0.79	1.29	1.19	**1.01**
C.V. (%)	5.49	7.73	5.24	3.28	3.03	2.06	2.88	2.37	**3.16**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different

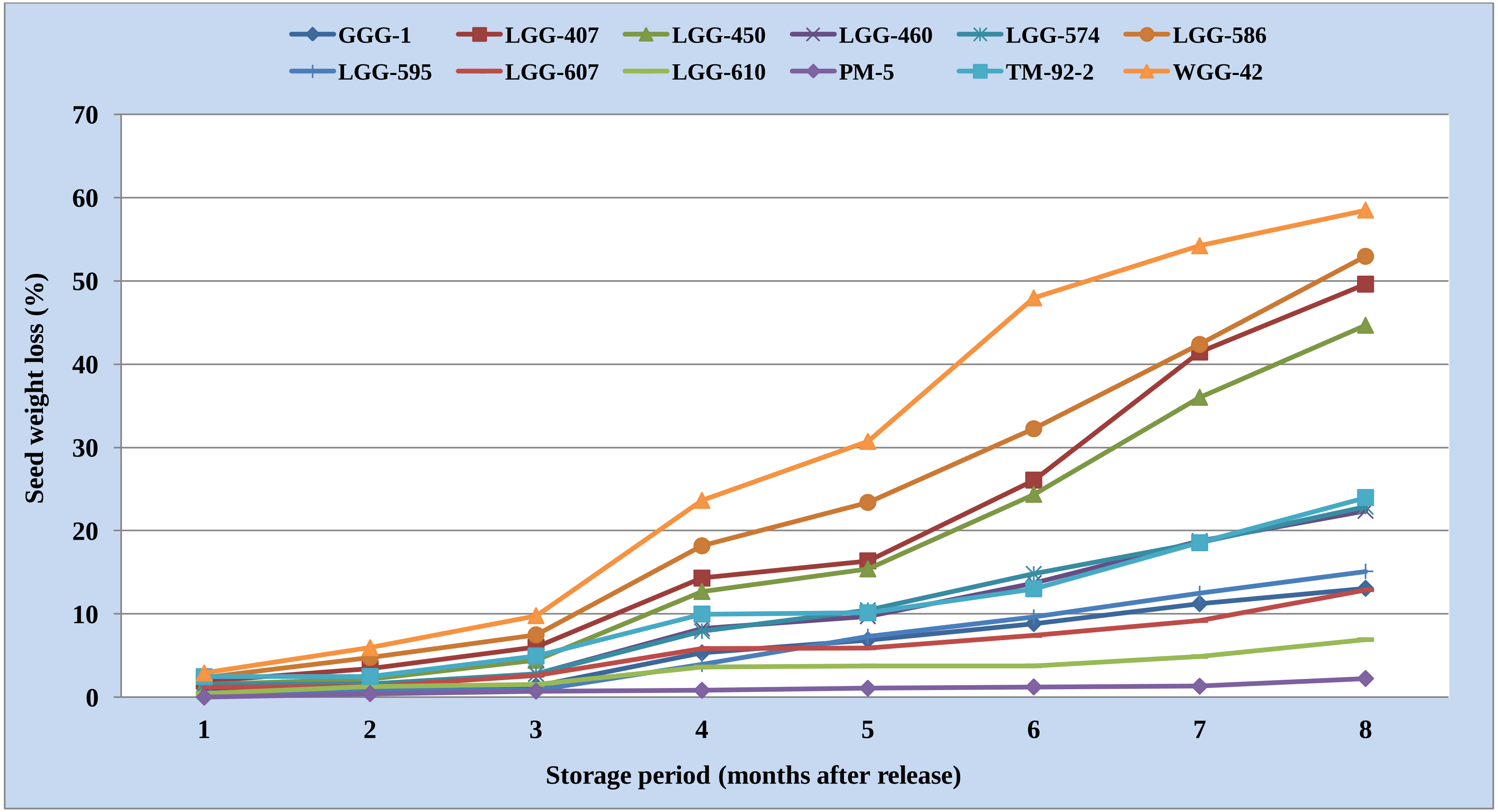


Figure 4.3. Weight loss (%) of seed in different greengram genotypes during storage after artificial infestation with pulse bruchid

Choudhary *et al*. (2015) reported that per cent grain weight loss due to infestation of *C. chinensis* in stored cowpea after six months clearly indicated that the lowest weight loss was observed in RCV-7 (1.73 %) and was at par with Divya-405 (1.76 %). Variety RC-19 recorded significantly highest weight loss (6.99 %) and was reported as the most preferred variety in their study.

In the present investigation, the genotypes which were least preferred by the *C. chinensis* for oviposition and adult emergence recorded less weight loss (2.24 %) against the highly preferred genotype which recorded a maximum weight loss of 58.51 %. The results are in confirmity with the findings of Khokhar andSingh (1987) who reported that pigeonpea variety, ICPL-143, with less number of eggs laid on seed andminimum adult emergence recorded minimum reductionin weight loss of 1.74 % as against the highly preferred variety which recorded amaximum weight loss of 88.69 %. Shivanna *et al*. (2011) stated that the weight loss wassignificantly less in CP-17 and Local variety of cowpea, which permitted highest number of larvae tofeed and develop, recorded significantly higher weight loss of grains.

4.1.1.4 Mean Development Period (days): Significant variation was observed in the mean development period of *C. chinensis* on different genotypes of greengram. The mean development period of bruchid ranged from 25.81 to 33.83 days among the different genotypes (Table 4.4 and Fig. 4.4). The longest mean development period was found on PM-5 (33.83 days) followed by GGG-1 (32.72 days) and LGG-607 (32.39 days) which were found to be on par with each other. Shortest mean development period (25.81 days) was recorded on WGG-42 followed by LGG-586 (26.56 days) and LGG-450 (26.78 days) which indicated that these genotypes favoured the development of bruchid, thus facilitating to complete more number of generations in a given period of time (Table 4.4). The results indicated that there was a large variation in mean development period of bruchid depending upon the host.

Divya *et al*. (2013a) reported that the mean development period of the *C. chinensis* ranged from 0.00 to 30.00 days on horsegram. Shortest mean development period of 8.67 days was recorded in the accessions KSAS/06/391, NSM-125, NS/04/57, PSRJ-13030, HG-35, NS/05/87, NS/05/94 and NSJ/NAIP/006-105, while longest mean developmental period was observed in NS/05/105 (30.00 days) for bruchid. Shinde *et al*. (2016) reported that the average developmental period ranged from 17 to 23 days on various cowpea varieties.

Table 4.4 Mean development period and growth index of pulse bruchid on different greengram genotypes after artificial infestation

Genotypes	Mean development period (days)	Growth index
GGG-1	32.72[a]	1.23[f]
LGG-407	28.56[d]	1.95[c]
LGG-450	26.78[e]	2.08[b]
LGG-460	30.06[cd]	1.68[d]
LGG-574	29.00[d]	1.76[d]
LGG-586	26.56[e]	2.17[b]
LGG-595	31.06[bc]	1.48[e]
LGG-607	32.39[ab]	1.06[g]
LGG-610	29.45[cd]	1.06[g]
PM-5	33.83[a]	1.05[h]
TM-92-2	28.89[d]	1.78[d]
WGG-42	25.81[e]	2.83[a]
Mean	29.59	1.60
F-test	Sig.	Sig.
SEm ±	0.54	0.04
C.D. (5%)	1.58	0.11
C.V. (%)	3.16	4.14

MAR: Months after release
Means in the same column showing similar alphabets are not significantly different

Table 4.5 Categorization of greengram genotypes based on growth index of *C. chinensis*

Category	**Growth index range**	**Number of greengram genotypes**	**Greengram genotypes**
Resistant	0 – 1.60	5	PM-5, LGG-610, LGG-607, GGG-1 and LGG-595
Moderately resistant	1.60 – 1.65	-	-
Moderately susceptible	1.65 – 1.70	1	LGG-460
Susceptible	1.70– 1.75	-	-
Highly susceptible	> 1.75	6	LGG-574, TM-92-2, LGG-407, LGG-450, LGG-586 and WGG-42

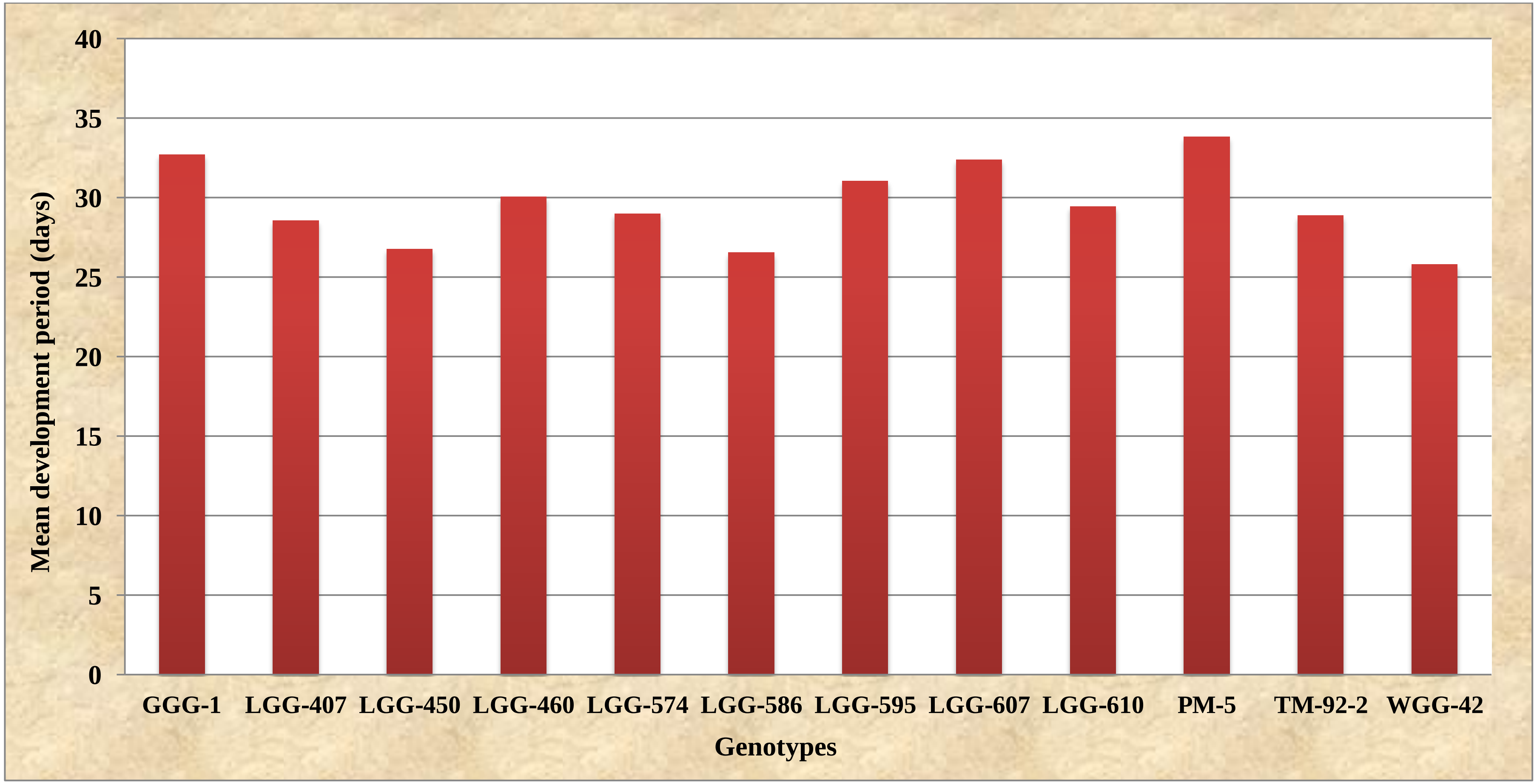


Figure 4.4. Mean development period of pulse bruchid on different greengram genotypes after artificial infestation

The results are in close proximity with that of Ofuya (1987), Chavan *et al.* (1997) and Singh and Sharma (2003) who reported that the development period was significantly longer in resistant varieties of cowpea than the susceptible varieties. Further, they also noted that it was prolonged by eight to ten days on least preferred cowpea varieties.

4.1.1.5 Growth Index: The experimental results presented in Table 4.4 and Fig. 4.5. indicated that the growth index of *C. chinensis* significantly differed among the different genotypes of greengram. The highest growth index was observed on WGG-42 (2.83) which might be due to highest oviposition and adult emergence and thus can be considered as most preferred genotype for the development of pulse bruchid. The lowest growth index was recorded on PM-5 (1.05). The next best genotypes with lower growth indices were LGG-607 (1.06), LGG-610 (1.06), and GGG-1 (1.23).

In the present study, growth index was calculated based on the adult emergence and developmental period of the pulse beetle and was taken as a criteria for categorization of genotypes as given by Mensah (1986). Out of 12 greengram genotypes used in the present investigation, five genotypes *viz.*, PM-5 (1.05), LGG-610 (1.06), LGG-607 (1.06), GGG-1 (1.23) and LGG-595 (1.48) were classified as resistant genotypes, while only one genotype, LGG-460 (1.68), was categorized as moderately susceptible and the remaining six genotypes *viz.*, LGG-574 (1.76), TM-92-2 (1.78), LGG-407 (1.95), LGG-450 (2.08), LGG-586 (2.17) and WGG-42 (2.83) were grouped as highly susceptible genotypes (Table 4.5).

The present findings are concurrent with Chavan *et al*. (1997), Singh and Sharma (2003) and Tripathi *et al*. (2015) who differentiated the various cultivars of cowpea into most susceptible and least susceptible groups on the basis of growth indices. They observed higher growth index values on susceptible varieties of various pulses. Sharma and Thakur (2014b) reported that among the different legumes, highest per cent of growth index (2.08-3.12) was recorded on cowpea genotypes, followed by chickpea (1.29-2.13) and least per cent growth index (0.00-0.36) was recorded on soybean genotypes. Dwivedi *et al*. (2016) reported that the growth index of *C. chinensis* on certain varieties of chickpea ranged from 1.59 to 1.83. The maximum growth index was found on variety PUSA-362 (1.83) and PG-186 (1.80) followed by KWR-108 (1.59).

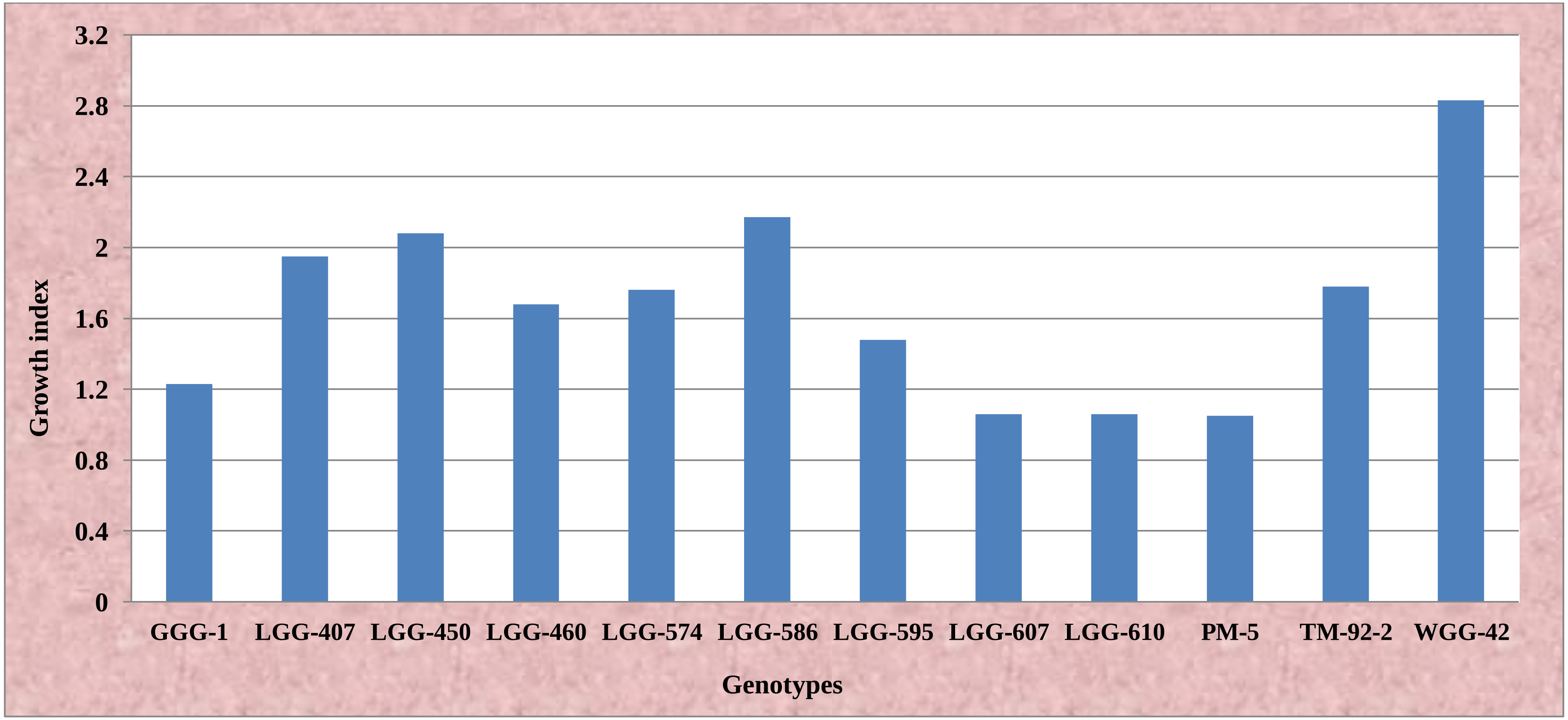


Figure 4.5. Growth index of pulse bruchid on different greengram genotypes after artificial infestation

4.1.2 Seed Quality Parameters

The data recorded at monthly interval upto eight months of storage on various seed quality parameters *i.e.,* seed moisture content, germination, seedling length, seedling vigour index and electrical conductivity of seed leachates were statistically analysed and the results are discussed here under:

4.1.2.1 Seed Moisture Content (%): The observation on moisture content of the greengram genotypes (Table 4.6) revealed that moisture content did not differ significantly. The moisture content increased slightly with the duration of storage. The mean moisture content in initial sample was 9.00 % which increased to 9.96 % after eight months of storage.

After eight months after storage, moisture content was low in PM-5 (9.40 %) followed by LGG-610 (9.50 %), GGG-1 (9.60 %) and LGG-607 (9.60 %). While the moisture content was high in WGG-42 (11.17 %). The pooled mean showed that the genotype, PM-5 recorded significantly minimum (9.20 %) moisture content, while maximum moisture content (10.04 %) was recorded in WGG-42 among the different genotypes (Table 4.6). The results indicated that the genotypes with more moisture content favours the development of bruchid and also recorded higher weight loss.

Choudhary *et al*. (2017) reported that the moisture percentage in different varieties of lentil varied from 10.50 to 12.96, being maximum in Sapna and minimum in Asha and stated that the higher per cent of moisture induce higher infestation of seed. The present results are in accordance with earlier report as the genotypes with high moisture content recorded higher damage after eight months after storage and *vice-versa*.

4.1.2.2 Germination (%): The germination of greengram genotypes was initially high but gradually decreased with increase in period of storage (Table 4.7). The mean germination decreased from 98.17 % (initial month) to 65.47 % after eighth months of storage. Significant differences were observed in germination among the genotypes irrespective of storage duration.

Initially, the germination varied from 99.00 to 97.00 % among the different genotypes without significant differences. After eight months of storage, significantly lowest germination was recorded in WGG-42 (28.67 %), while, significantly highest

Table 4.6 Moisture content (%) of seed in different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Moisture content (%)									
	Initial	**1 MAR**	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
GGG-1	9.00 (17.45)	9.03 (17.48)^{ef}	9.13 (17.58)^{c}	9.17 (17.62)^{e}	9.30 (17.75)^{fg}	9.40 (17.85)^{e}	9.53 (17.98)^{f}	9.60 (18.04)^{g}	9.60 (18.04)^{g}	**9.31 (17.76)^{g}**
LGG-407	9.00 (17.45)	9.13 (17.58)^{de}	9.23 (17.68)^{bc}	9.37 (17.81)^{bc}	9.47 (17.91)^{cd}	9.67 (18.11)^{c}	9.93 (18.36)^{c}	10.13 (18.55)^{c}	10.27 (18.68)^{c}	**9.58 (18.02)^{c}**
LGG-450	9.00 (17.45)	9.20 (17.65)^{bcd}	9.27 (17.72)^{b}	9.37 (17.81)^{bc}	9.53 (17.98)^{c}	9.63 (18.07)^{c}	9.83 (18.27)^{d}	10.00 (18.43)^{d}	10.20 (18.62)^{d}	**9.56 (18.00)^{c}**
LGG-460	9.00 (17.45)	9.13 (17.58)^{de}	9.23 (17.68)^{bc}	9.27 (17.72)^{cde}	9.37 (17.81)^{ef}	9.50 (17.94)^{d}	9.67 (18.11)^{e}	9.77 (18.20)^{f}	9.90 (18.33)^{f}	**9.43 (17.87)^{e}**
LGG-574	9.00 (17.45)	9.23 (17.68)^{bcd}	9.30 (17.75)^{b}	9.33 (17.78)^{c}	9.43 (17.88)^{de}	9.50 (17.94)^{d}	9.70 (18.14)^{e}	9.77 (18.20)^{f}	9.87 (18.30)^{f}	**9.46 (17.90)^{e}**
LGG-586	9.00 (17.45)	9.30 (17.75)^{b}	9.33 (17.78)^{b}	9.47 (17.91)^{b}	9.73 (18.17)^{b}	9.93 (18.36)^{b}	10.20 (18.62)^{b}	10.50 (18.90)^{b}	10.47 (18.87)^{b}	**9.77 (18.21)^{b}**
LGG-595	9.00 (17.45)	9.00 (17.45)^{f}	9.13 (17.58)^{c}	9.27 (17.72)^{cde}	9.30 (17.75)^{fg}	9.37 (17.81)^{e}	9.50 (17.94)^{fg}	9.53 (17.98)^{gh}	9.60 (18.04)^{g}	**9.30 (17.75)^{gh}**
LGG-607	9.00 (17.45)	9.17 (17.62)^{cd}	9.23 (17.68)^{bc}	9.30 (17.75)^{cd}	9.33 (17.78)^{fg}	9.40 (17.85)^{e}	9.50 (17.94)^{fg}	9.57 (18.01)^{gh}	9.60 (18.04)^{g}	**9.34 (17.79)^{f}**
LGG-610	9.00 (17.45)	9.03 (17.48)^{ef}	9.13 (17.58)^{c}	9.20 (17.65)^{de}	9.27 (17.72)^{gh}	9.37 (17.81)^{e}	9.43 (17.88)^{g}	9.50 (17.94)^{h}	9.50 (17.94)^{h}	**9.27 (17.72)^{h}**
PM-5	9.00 (17.45)	9.03 (17.48)^{ef}	9.13 (17.58)^{c}	9.17 (17.62)^{e}	9.20 (17.65)^{h}	9.23 (17.68)^{f}	9.30 (17.75)^{h}	9.30 (17.75)^{i}	9.40 (17.85)^{i}	**9.20 (17.65)^{i}**
TM-92-2	9.00 (17.45)	9.27 (17.72)^{bc}	9.30 (17.75)^{b}	9.37 (17.81)^{bc}	9.47 (17.91)^{cd}	9.63 (18.07)^{c}	9.80 (18.24)^{d}	9.90 (18.33)^{e}	10.00 (18.43)^{e}	**9.53 (17.97)^{d}**
WGG-42	9.00 (17.45)	9.43 (17.88)^{a}	9.53 (17.98)^{a}	9.73 (18.17)^{a}	9.97 (18.40)^{a}	10.23 (18.65)^{a}	10.50 (18.90)^{a}	10.83 (19.21)^{a}	11.17 (19.51)^{a}	**10.04 (18.47)^{a}**
Mean	9.00 (17.45)	9.16 (17.61)	9.25 (17.70)	9.33 (17.78)	9.45 (17.89)	9.57 (18.01)	9.74 (18.18)	9.87 (18.30)	9.96 (18.39)	**9.48 (17.93)**
F-test	NS	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
SEm ±	-	0.03	0.03	0.03	0.03	0.03	0.02	0.02	0.02	**0.01**
C.D. (5%)	-	0.10	0.09	0.10	0.08	0.08	0.06	0.07	0.05	**0.03**
C.V. (%)	-	0.33	0.29	0.33	0.27	0.25	0.20	0.21	0.17	**0.11**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different

germination was recorded in PM-5 (84.33 %). The other genotypes which recorded higher germination were LGG-610 (78.33 %), LGG-607 (75.33 %) and GGG-1 (74.67 %) which were found at par with each other (Table 4.7).

The pooled data showed that the genotype, PM-5 recorded significantly highest germination (91.26 %). The other genotypes which recorded highest germination were GGG-1 (87.07 %), LGG-610 (86.41 %), LGG-460 (85.70 %), LGG-607 (85.44 %), LGG-595 (84.85 %), TM-92-2 (84.41 %) and LGG-574 (83.81 %) which were found at par with each other. The genotype, WGG-42 (60.74 %) recorded significantly lowest germination (Table 4.7).

The per cent reduction in germination in comparison to initial germination was 14.82, 20.88 and 23.13 in PM-5, LGG-610 and LGG-607, respectively at eight months after storage. Whereas in WGG-42, the per cent germination drastically reduced from 97.00 to 28.67 leading to 70.44 per cent reduction over initial germination (Fig. 4.6). This clearly indicated that there was a significant decrease in per cent germination due to the infestation of the *C. chinensis* which canbe attributed to higher weight loss or more damage to the cotyledons of seed or damage to embryo of the seed. Some of the seed germinated but died eventually within one or two days as observed in laboratory study which might be due to lack of food material supply from damaged cotyledons.

The results are in close proximity with the findings of Patro *et al*. (2005) and Parmar and Patel (2016)who observed that the germination in greengram decreased with increase in seed damage and period of storage. Significant reduction in germination due to artificial infestation by *C. chinensis* under lab conditions was reported in cowpea (Deshpande *et al.*, 2011 and Choudhary *et al*., 2015). Raja *et al.* (2004) observed a significant decrease in germinationof greengram seed with increase in the level of bruchid infestation.

4.1.2.3 Seedling Length (cm): The length of seedlings emerged from initial sample was high but gradually decreased with increase in period of storage of seed (Table 4.8). The mean seedling length varies widely from initial month (32.40 cm) to eighth month of storage (17.68 cm). The seedling length differed significantly among the genotypes at different periods of storage.

Table 4.7 Germination (%) of seed in different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Germination (%)									
	Initial	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
GGG-1	99.00 (85.34)^{a}	95.67 (78.07)^{bcd}	93.33 (75.02)^{ab}	90.33 (71.86)^{ab}	87.33 (69.23)^{ab}	84.67 (66.92)^{b}	81.33 (64.38)^{bc}	77.33 (61.63)^{bc}	74.67 (59.76)^{bc}	**87.07 (68.91)^{b}**
LGG-407	97.00 (80.09)^{a}	92.33 (73.90)^{efg}	87.00 (68.85)^{de}	84.00 (66.40)^{c}	73.33 (58.91)^{d}	70.33 (56.98)^{d}	65.33 (53.94)^{e}	60.67 (51.16)^{e}	56.33 (48.62)^{d}	**76.26 (60.82)^{c}**
LGG-450	98.00 (82.02)^{a}	90.67 (72.34)^{fg}	85.33 (67.46)^{e}	83.67 (66.25)^{c}	75.67 (60.50)^{d}	72.67 (58.46)^{d}	70.33 (57.03)^{d}	65.67 (54.11)^{d}	60.67 (51.14)^{d}	**78.07 (62.06)^{c}**
LGG-460	98.00 (82.02)^{a}	95.33 (77.51)^{cd}	92.67 (74.27)^{ab}	89.67 (71.44)^{ab}	84.00 (66.40)^{c}	82.67 (65.38)^{bc}	80.00 (63.41)^{bc}	76.67 (61.09)^{c}	72.33 (58.24)^{c}	**85.70 (67.76)^{b}**
LGG-574	99.00 (85.34)^{a}	92.67 (74.29)^{efg}	87.67 (69.43)^{de}	84.00 (66.42)^{c}	82.67 (65.38)^{c}	81.33 (64.38)^{bc}	79.33 (62.94)^{bc}	76.33 (60.87)^{c}	71.33 (57.61)^{c}	**83.81 (66.25)^{b}**
LGG-586	97.00 (80.09)^{a}	94.33 (76.34)^{cde}	91.33 (72.89)^{bc}	84.67 (67.11)^{c}	65.67 (54.11)^{e}	60.67 (51.15)^{e}	54.67 (47.66)^{f}	45.67 (42.50)^{f}	40.33 (39.93)^{e}	**70.48 (57.07)^{d}**
LGG-595	99.00 (85.34)^{a}	97.33 (80.61)^{ab}	92.67 (74.27)^{ab}	85.33 (67.46)^{c}	83.33 (65.88)^{c}	80.33 (63.65)^{c}	79.00 (62.70)^{c}	75.00 (59.98)^{c}	71.67 (57.82)^{c}	**84.85 (67.07)^{b}**
LGG-607	98.00 (82.02)^{a}	96.00 (78.49)^{bc}	89.00 (70.75)^{cd}	86.33 (68.37)^{bc}	84.67 (66.92)^{bc}	81.67 (64.62)^{bc}	80.33 (63.65)^{bc}	77.67 (61.77)^{bc}	75.33 (60.27)^{bc}	**85.44 (67.72)^{b}**
LGG-610	99.00 (85.34)^{a}	93.67 (75.40)^{cdef}	87.67 (69.48)^{de}	86.33 (68.29)^{bc}	85.33 (67.46)^{bc}	84.33 (66.86)^{b}	82.67 (65.37)^{b}	80.33 (63.65)^{b}	78.33 (62.24)^{b}	**86.41 (68.47)^{b}**
PM-5	99.00 (85.34)^{a}	98.33 (82.63)^{a}	95.00 (77.09)^{a}	92.67 (74.27)^{a}	90.00 (71.54)^{a}	88.67 (70.30)^{a}	87.67 (69.42)^{a}	85.67 (67.73)^{a}	84.33 (66.66)^{a}	**91.26 (72.77)^{a}**
TM-92-2	98.00 (82.02)^{a}	93.33 (75.02)^{defg}	91.33 (72.92)^{bc}	84.00 (66.40)^{c}	83.67 (66.14)^{c}	82.67 (65.37)^{bc}	79.67 (63.17)^{bc}	75.33 (60.20)^{c}	71.67 (57.82)^{c}	**84.41 (66.72)^{b}**
WGG-42	97.00 (80.09)^{a}	90.33 (71.92)^{g}	73.33 (58.91)^{f}	72.33 (58.24)^{d}	57.67 (49.39)^{f}	51.00 (45.55)^{f}	42.67 (40.77)^{g}	33.67 (35.45)^{g}	28.67 (32.36)^{f}	**60.74 (51.18)^{e}**
Mean	98.17 (82.92)	94.17 (76.38)	88.86 (70.94)	85.28 (67.71)	79.44 (63.49)	76.75 (61.64)	73.58 (59.54)	69.17 (56.68)	65.47 (54.37)	**81.21 (64.73)**
F-test	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	1.78	0.96	0.92	1.24	0.87	0.86	0.77	0.80	1.04	**1.04**
C.D. (5%)	5.19	1.41	2.69	3.61	2.55	2.51	2.24	2.33	3.03	**3.04**
C.V. (%)	3.72	2.18	2.25	3.17	2.38	2.41	2.24	2.44	3.31	**2.78**

MAR: Months after release

Figures in parenthesis are arc sine transformed values

Means in the same column showing similar alphabets are not significantly different

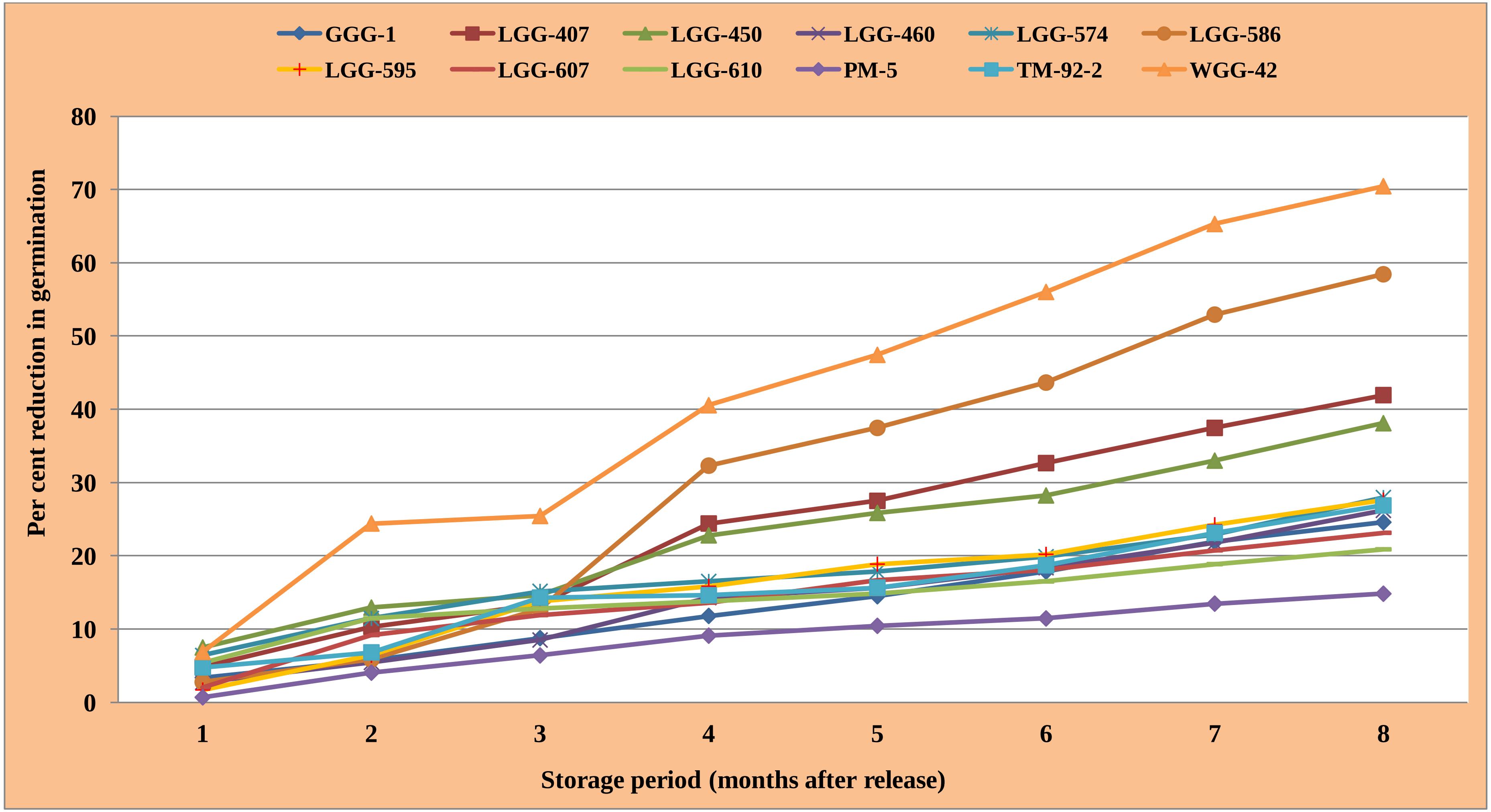


Figure 4.6. Per cent reduction in germination in different greengram genotypes during storage after artificial infestation with pulse bruchid

Initially, the seedling length varied from 30.94 to 33.64 cm among the different genotypes. The seedling length was significantly highest in the genotype, PM-5 (33.64 cm) followed by LGG-574 (33.60 cm), LGG-460 (33.45 cm), LGG-607 (32.77 cm) and LGG-586 (32.52 cm). The seedling length was low in LGG-450 (30.94 cm) followed by TM-92-2 (31.08 cm) and LGG-407 (31.21 cm) and were found at par with each other. Almost similar trend in variation in seedling length was observed during the subsequent months of storage among different greengram genotypes (Table 4.8).

At eight months after storage, longer seedlings were observed in PM-5 (27.92 cm), which was significantly superior over all the other genotypes. The next best genotypes with high seedling length were LGG-595 (23.52 cm), LGG-610 (23.41 cm) and LGG-607 (22.47 cm) which were found at par with each other. The seedling length was significantly low in WGG-42 (9.17 cm) followed by LGG-586 (10.81 cm) (Table 4.8).

The pooled data showed that the genotype, PM-5 recorded significantly highest seedling length (30.66 cm), while WGG-42 recorded significantly lowest seedling length (18.79 cm) (Table 4.8) among all the genotypes.

From the data, it is evident that the genotypes with more weight loss recorded the lowest seedling length and *vice-versa*. This can be attributed to the less availability of food material for growth of germinated seedling due to more damaged portion of cotyledons of seed. The per cent decrease in seedling length due to the infestation by pulse bruchid in comparison to initial seedling length was more in WGG-42 (71.17 %) while it was least in PM-5 (17.00 %) at eight months after storage (Fig. 4.7). The decrease in seedling length due to the infestation of *C. chinensis* maybe due to decrease in both root and shoot length. Similar findings were reported by Deshpande *et al.* (2011) who stated that the infestation of *C. maculatus*,significantly reduced the seedling length of cowpea accessions. Similar results were obtained by Lakshminarasimhiah (1993) in pigeonpea, Hanumantappa (1996) in horsegram, Patil *et al.* (2003) in chickpea and Nagaraja (2006) in cowpea.

4.1.2.4 Seedling Vigour Index: The seedling vigour indexwas initially high but decreased with increase in period of storage among all the genotypes (Table 4.9). The mean seedling vigour index varied widely from 3181 in initial month to 1231 in eighth month of storage. Significant difference in seedling vigour indexwas observed among all the genotypes at different periods of storage.

Table 4.8 Seedling length of different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Seedling length (cm)									
	Initial	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
GGG-1	32.12^{ab}	31.62^{a}	30.41^{ab}	29.62^{a}	27.41^{bc}	23.25^{c}	22.28^{c}	21.34^{c}	20.21^{c}	**26.47^{bc}**
LGG-407	31.21^{b}	29.30^{b}	26.62^{d}	23.47^{f}	20.28^{g}	18.47^{fg}	17.28^{e}	15.59^{e}	13.79^{e}	**21.78^{e}**
LGG-450	30.94^{b}	28.67^{b}	26.62^{d}	23.29^{f}	22.18^{e}	19.96^{ef}	17.62^{e}	15.48^{e}	13.61^{e}	**22.04^{e}**
LGG-460	33.45^{a}	32.54^{a}	30.69^{ab}	28.72^{ab}	24.93^{d}	21.83^{cd}	20.28^{d}	18.56^{d}	17.17^{d}	**25.35^{cd}**
LGG-574	33.60^{a}	32.41^{a}	29.88^{b}	25.45^{cde}	21.84^{ef}	20.72^{de}	19.34^{d}	17.62^{d}	16.31^{d}	**24.13^{d}**
LGG-586	32.52^{ab}	31.28^{a}	28.69^{bc}	25.13^{def}	20.54^{fg}	17.61^{g}	15.03^{f}	13.41^{f}	10.81^{f}	**21.67^{e}**
LGG-595	33.19^{a}	32.74^{a}	32.20^{a}	29.91^{a}	28.13^{b}	25.88^{b}	25.62^{b}	24.58^{b}	23.52^{b}	**28.42^{b}**
LGG-607	32.77^{ab}	31.47^{a}	30.40^{ab}	27.23^{bc}	26.83^{bc}	25.08^{b}	24.15^{b}	23.26^{b}	22.47^{b}	**27.07^{bc}**
LGG-610	32.41^{ab}	31.39^{a}	28.88^{bc}	26.90^{bcd}	26.40^{c}	26.29^{b}	25.41^{b}	24.64^{b}	23.41^{b}	**27.30^{bc}**
PM-5	33.64^{a}	32.65^{a}	31.98^{a}	30.53^{a}	30.36^{a}	30.34^{a}	29.67^{a}	28.82^{a}	27.92^{a}	**30.66^{a}**
TM-92-2	31.08^{b}	29.25^{b}	27.85^{cd}	23.94^{ef}	20.34^{g}	18.95^{fg}	17.10^{e}	15.20^{e}	13.75^{e}	**21.94^{e}**
WGG-42	31.81^{ab}	29.18^{b}	24.40^{e}	18.70^{g}	17.16^{h}	14.45^{h}	12.91^{g}	11.28^{g}	9.17^{g}	**18.79^{f}**
Mean	32.40	31.04	29.05	26.07	23.87	21.90	20.56	19.15	17.68	**24.64**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.58	0.48	0.63	0.60	0.45	0.50	0.48	0.45	0.48	**0.54**
C.D. (5%)	1.69	1.40	1.83	1.77	1.31	1.47	1.41	1.32	1.39	**1.57**
C.V. (%)	3.09	2.68	3.73	4.02	3.27	3.97	4.07	4.09	4.66	**3.78**

MAR: Months after release

Means in the same column showing similar alphabets are not significantly different

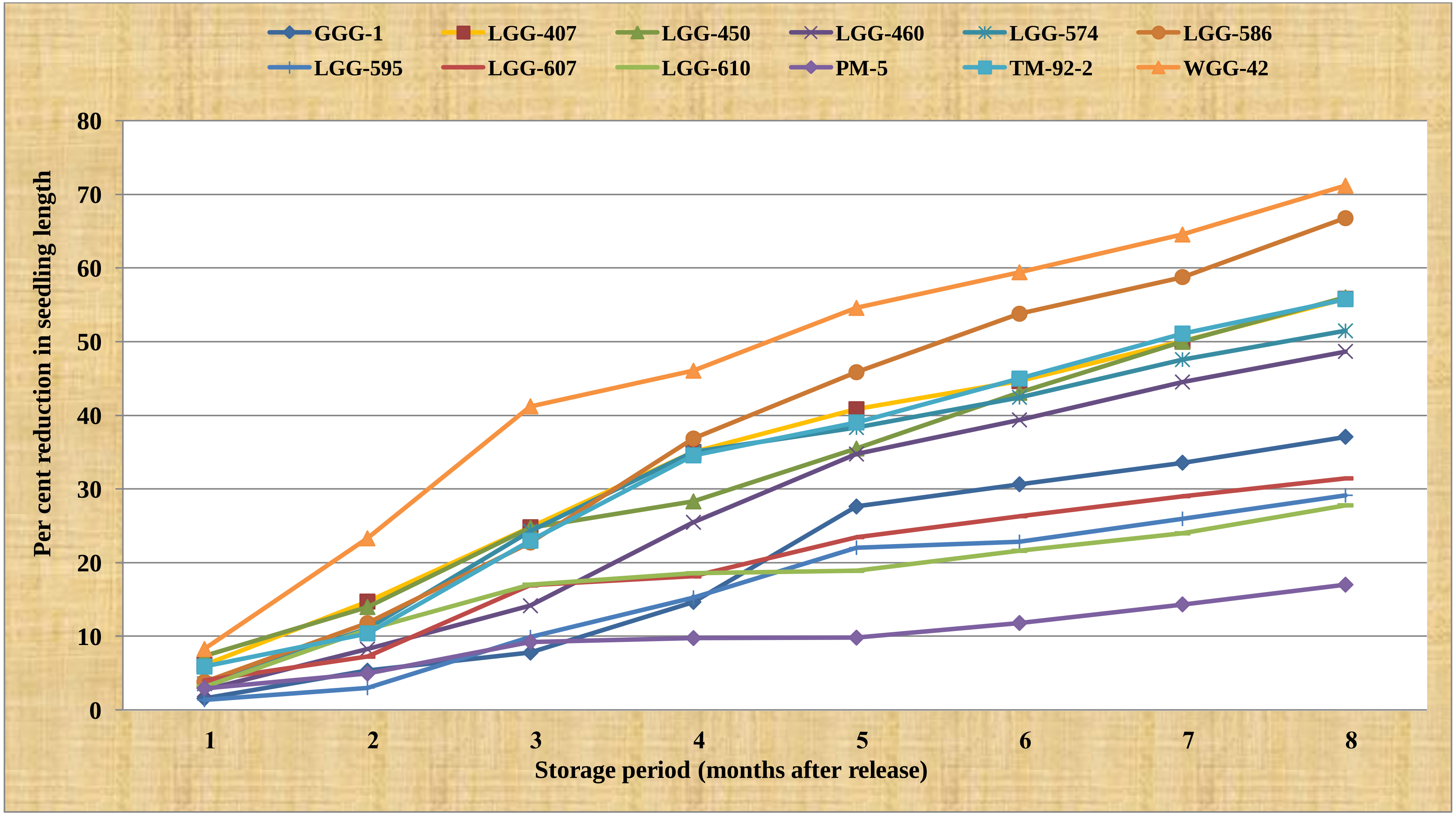


Figure 4.7. Per cent reduction in seedling length of different greengram genotypes during storage after artificial infestation with pulse bruchid

Initially, the seedling vigour index varied from 3330 to 3027 among the different genotypes. The seedling vigour index was significantly highest in the genotype, PM-5 (3330) followed by LGG-595 (3286) and LGG-460 (3278). Significantly lowest seedling vigour index was observed in LGG-470 (3027) followed by LGG-450 (3032), TM-92-2 (3046) and WGG-42 (3086) which were found at par among themselves. Almost similar trend was observed during the subsequent months of storage with significant differences among the different genotypes (Table 4.9).

After eight months of storage, significantly lowest seedling vigour indexwas recorded in WGG-42 (263). The highest seedling vigour indexwas recorded in PM-5 (2355) followed by LGG-610 (1834) which were significantly superior over the other remaining genotypes (Table 4.9).

The pooled data showed that the genotype, PM-5 recorded significantly highest seedling vigour index (2806). The other genotypes which recorded high seedling vigour index were LGG-595 (2443), LGG-610 (2376), GGG-1 (2339) and LGG-607 (2338) which were found at par with each other. The genotype, WGG-42 (1309) recorded lowest seedling vigour index which was significantly lowest among all the genotypes (Table 4.9).

The per cent decrease in seedling vigour index due to the infestation by pulse bruchid in comparison to initial seedling vigour index was more in WGG-42 (91.00 %) while it was least in PM-5 (29.00 %) at eight months after storage (Fig. 4.8). From the data, it is evident that the genotypes with less damage and per cent weight loss recorded higher seedling vigour index. The low vigour index in seed might be due to the damage to the vital germinable portion of seed by the young developing grubs. Completely hollowed seed failed to germinate. However, the seedling vigour is further dependent on other factors such as thickness of seed coat, colour, nutrient status, presence of antixenotic chemicals *etc.*, which vary with variety.

The germination and total seedling length were higher in the genotype PM-5, hence seedling vigour index was also found to be high in that genotype. The genotype, WGG-42, which recorded low germination and less seedling length recorded lower seedling vigour index. The results are in confirmity with the findings of Southgate (1979) who reported greater reduction in seedling vigour with increase in the infestation of pulse beetle in greengram. Raja *et al.* (2004) found that there was significant

Table 4.9 Seedling vigour index of different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Seedling vigour index									
	Initial	**1 MAR**	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
GGG-1	3180^{ab}	3025^{bc}	2838^{b}	2675^{ab}	2394^{b}	1969^{c}	1812^{d}	1650^{d}	1509^{d}	**2339^{bc}**
LGG-407	3027^{b}	2705^{d}	2316^{e}	1973^{de}	1487^{g}	1299^{h}	1129^{h}	946^{g}	777^{g}	**1740^{f}**
LGG-450	3032^{b}	2599^{d}	2272^{e}	1957^{e}	1678^{f}	1451^{g}	1239^{g}	1016^{g}	825^{g}	**1786^{ef}**
LGG-460	3278^{a}	3102^{ab}	2844^{b}	2575^{b}	2094^{d}	1805^{d}	1622^{e}	1423^{e}	1242^{e}	**2221^{c}**
LGG-574	3326^{a}	3004^{bc}	2619^{cd}	2138^{d}	1805^{e}	1685^{e}	1534^{e}	1345^{e}	1163^{e}	**2069^{d}**
LGG-586	3154^{ab}	2950^{c}	2620^{cd}	2127^{d}	1349^{h}	1069^{i}	822^{i}	612^{h}	436^{h}	**1682^{f}**
LGG-595	3286^{a}	3186^{a}	2984^{a}	2552^{b}	2344^{bc}	2079^{c}	2024^{bc}	1844^{c}	1686^{c}	**2443^{b}**
LGG-607	3211^{ab}	3021^{bc}	2702^{c}	2315^{c}	2305^{bc}	2048^{c}	1940^{c}	1806^{c}	1693^{c}	**2338^{bc}**
LGG-610	3209^{ab}	2940^{c}	2531^{d}	2322^{c}	2253^{c}	2217^{b}	2100^{b}	1980^{b}	1834^{b}	**2376^{bc}**
PM-5	3330^{a}	3211^{a}	3038^{a}	2829^{a}	2732^{a}	2690^{a}	2601^{a}	2469^{a}	2355^{a}	**2806^{a}**
TM-92-2	3046^{b}	2730^{d}	2544^{d}	2010^{de}	1702^{f}	1567^{f}	1362^{f}	1145^{f}	986^{f}	**1899^{e}**
WGG-42	3086^{b}	2636^{d}	1789^{f}	1353^{f}	990^{i}	737^{j}	551^{j}	380^{i}	263^{i}	**1309^{g}**
Mean	3180	2926	2591	2236	1928	1717.91	1561	1385	1231	**2084**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	57.74	44.88	38.90	53.65	29.59	37.68	35.10	35.40	34.11	**55.14**
C.D. (5%)	168.52	131.00	113.55	156.59	86.37	110.00	102.46	103.32	99.56	**160.96**
C.V. (%)	3.14	2.66	2.60	4.16	2.66	3.80	3.89	4.43	4.80	**4.58**

MAR: Months after release

Means in the same column showing similar alphabets are not significantly different

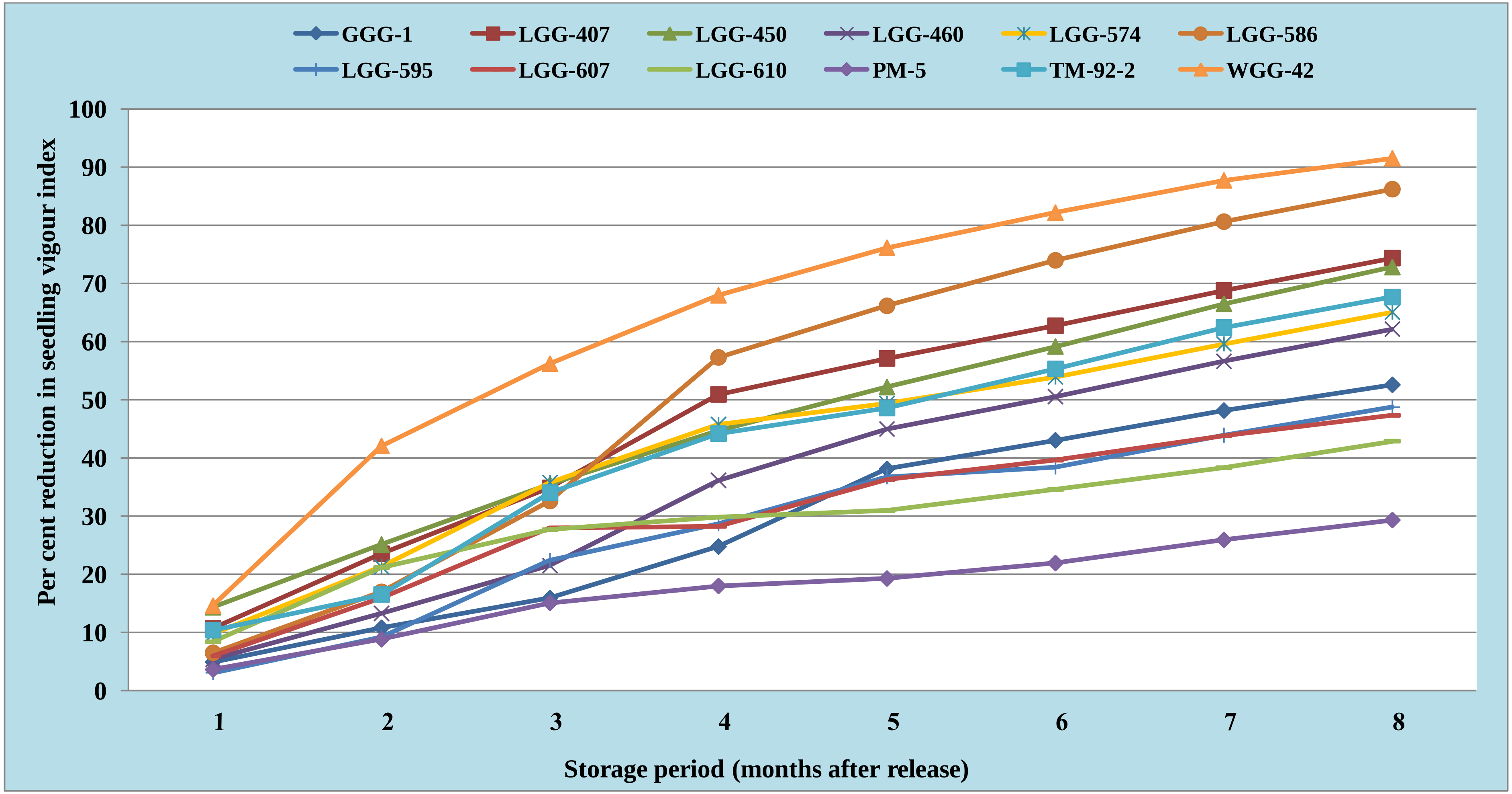


Figure 4.8. Per cent reduction in seedling vigour index of different greengram genotypes during storage after artificial infestation with pulse bruchid

decrease in seedling vigour index with increased level of bruchid infestation in greengram.Parameshwarappa *et al.* (2007) reported that the chickpea genotype, ICCV-03311 was least susceptible with high seedling vigour index at 60 days after release of bruchids in storage when compared to other varieties of chickpea. Deshpande *et al.* (2011) stated that with the infestation of pulse beetle reduced the seedling vigour of cowpea accessions.

4.1.2.5 Electrical Conductivity of Seed Leachates (dSm^{-1}): The electrical conductivity increased with increase in period of storage after artificial infestation of bruchids (Table 4.10 and Fig. 4.9). The mean electrical conductivity was low during initial month (0.40 dSm^{-1}) which increased gradually to eighth month of storage (1.95 dSm^{-1}). A significant difference in electrical conductivity was observed among all the genotypes irrespective of storage duration.

The electrical conductivity varied from 0.40 to 0.60 dSm^{-1} among the different genotypes during the first month. The electrical conductivity was significantly low and same (0.40 dSm^{-1}) in the genotypes PM-5, LGG-610, LGG-607, LGG-595 and GGG-1. The genotypes WGG-42 and LGG-586 recorded 0.60 dSm^{-1} among which the seed weight loss was high. Almost similar trend was observed during the subsequent months of storage among the genotypes (Table 4.10).

After eight months of storage, the electrical conductivity increased in all the genotypes. Lowest electrical conductivity was recorded in PM-5 (1.07 dSm^{-1}) followed by LGG-595 (1.23 dSm^{-1}). Highest electrical conductivity was recorded in WGG-42 (3.23 dSm^{-1}) followed by LGG-586 (3.07 dSm^{-1}) (Table 4.10).

The pooled data showed that the genotype, PM-5 (0.69 dSm^{-1}) recorded significantly lowest electrical conductivity. The other genotypes which recorded low electrical conductivity were GGG-1 (0.84 dSm^{-1}), LGG-607 (0.84 dSm^{-1}) and LGG-610 (0.87 dSm^{-1}) and were found at par with each other. The genotype, WGG-42 (1.84 dSm^{-1}) recorded significantly high electrical conductivity followed by LGG-586 (1.71 dSm^{-1}) (Table 4.10).

The data clearly indicated that the genotypes which recorded high moisture content showed higher electrical conductivity and higher weight loss and *vice-versa*. The variation in electrical conductivity was mainly due to variation in infestation level and also inherent response of each genotype to the attack of bruchid. Similar results

Table 4.10 Electrical conductivity (dSm^{-1}) of seed leachate in different greengram genotypes during storage after artificial infestation with pulse bruchid

Genotypes	Electrical conductivity (dSm^{-1})									
	Initial	**1 MAR**	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
GGG-1	0.40	0.40^{d}	0.47^{f}	0.77^{e}	0.93^{f}	1.03^{g}	1.10^{g}	1.17^{f}	1.30^{fg}	$\mathbf{0.84^{f}}$
LGG-407	0.40	0.50^{c}	0.63^{cde}	1.23^{b}	1.43^{d}	1.73^{d}	1.93^{d}	2.27^{d}	2.67^{c}	$\mathbf{1.42^{c}}$
LGG-450	0.40	0.47^{c}	0.57^{e}	1.30^{b}	1.53^{c}	1.83^{c}	2.07^{c}	2.40^{c}	2.73^{c}	$\mathbf{1.47^{c}}$
LGG-460	0.40	0.50^{b}	0.57^{e}	0.90^{d}	1.13^{e}	1.20^{f}	1.30^{f}	1.53^{e}	1.77^{e}	$\mathbf{1.03^{e}}$
LGG-574	0.40	0.50^{b}	0.87^{b}	1.07^{c}	1.17^{e}	1.23^{ef}	1.37^{e}	1.60^{e}	1.87^{d}	$\mathbf{1.12^{d}}$
LGG-586	0.40	0.60^{a}	0.70^{c}	1.53^{a}	1.87^{b}	2.13^{b}	2.40^{b}	2.73^{b}	3.07^{b}	$\mathbf{1.71^{b}}$
LGG-595	0.40	0.40^{d}	0.57^{e}	0.63^{f}	0.73^{g}	0.83^{h}	0.90^{i}	1.03^{gh}	1.23^{g}	$\mathbf{0.75^{g}}$
LGG-607	0.40	0.40^{d}	0.60^{de}	0.90^{d}	0.90^{f}	0.97^{g}	1.00^{h}	1.13^{fg}	1.30^{fg}	$\mathbf{0.84^{f}}$
LGG-610	0.40	0.40^{d}	0.67^{cd}	0.87^{d}	0.97^{f}	1.00^{g}	1.03^{h}	1.17^{f}	1.33^{f}	$\mathbf{0.87^{f}}$
PM-5	0.40	0.40^{d}	0.47^{f}	0.67^{f}	0.70^{g}	0.77^{h}	0.80^{j}	0.93^{h}	1.07^{h}	$\mathbf{0.69^{g}}$
TM-92-2	0.40	0.50^{b}	0.60^{de}	0.93^{d}	1.13^{e}	1.30^{e}	1.40^{e}	1.57^{e}	1.80^{de}	$\mathbf{1.07^{de}}$
WGG-42	0.40	0.60^{a}	1.03^{a}	1.57^{a}	2.07^{a}	2.23^{a}	2.53^{a}	2.93^{a}	3.23^{a}	$\mathbf{1.84^{a}}$
Mean	0.40	0.47	0.64	1.03	1.21	1.36	1.49	1.71	1.95	**1.14**
F-test	NS	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	-	0.01	0.03	0.03	0.03	0.03	0.02	0.03	0.03	**0.02**
C.D. (5%)	-	0.03	0.08	0.10	0.09	0.08	0.06	0.10	0.08	**0.07**
C.V. (%)	-	3.53	7.76	5.60	4.34	3.69	2.51	3.52	2.57	**3.41**

MAR: Months after release
Means in the same column showing similar alphabets are not significantly different

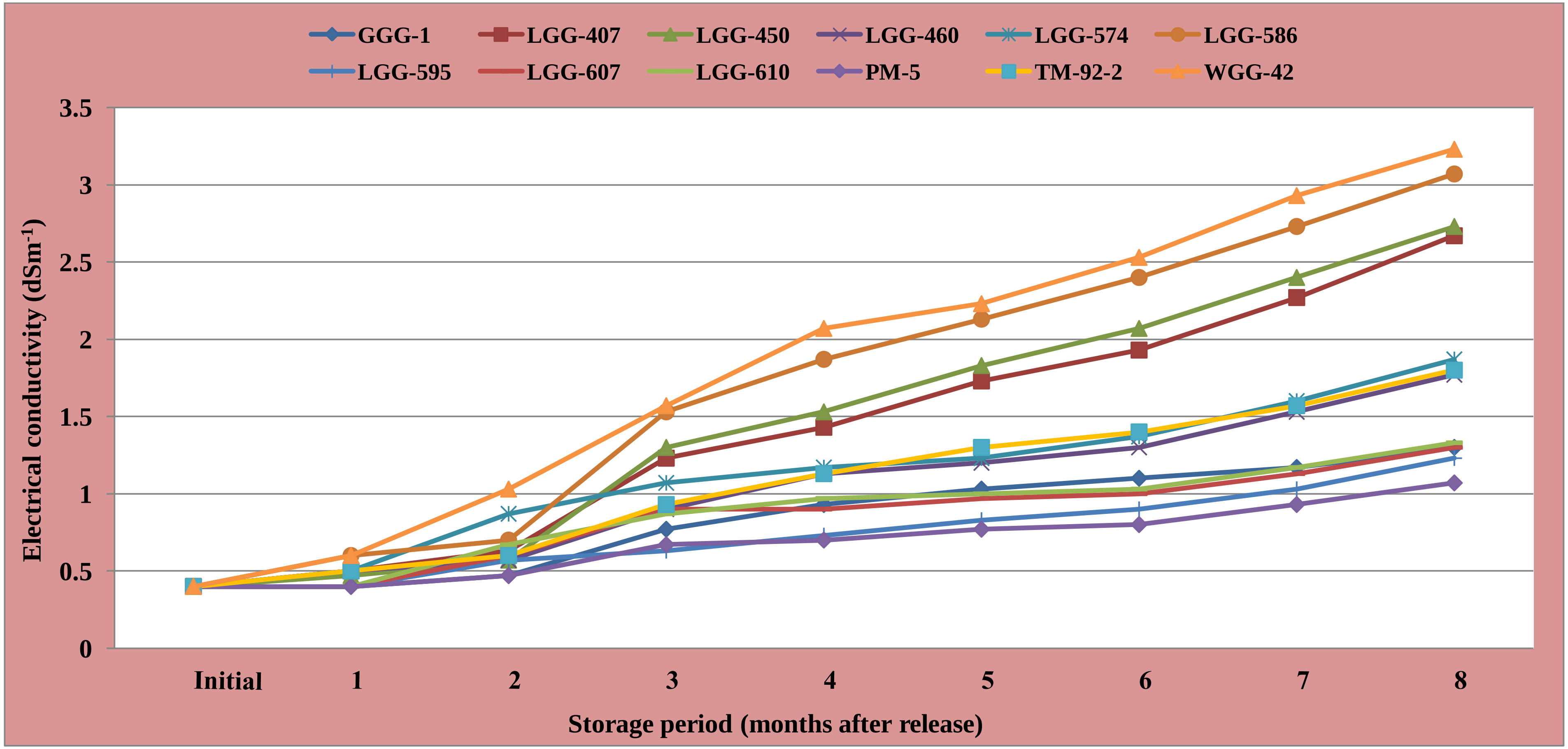


Figure 4.9. Electrical conductivity (dSm^{-1}) of seed leachate in different greengram genotypes during storage after artificial infestation with pulse

with respect to electrical conductivity was reported by Lakshminarasimhaiah (1993) in pigeonpea, Biradarpatil *et al.* (1995) in chickpea, Hanumantappa (1996) in horsegram, Patil *et al.* (2003) in chickpea, Nagaraja (2006), Bhaduria and Jakhmola (2006) in cowpea and Parameshwarappa *et al.* (2007) in chickpea.

4.2 STUDIES ON THE PHYSICO-CHEMICAL PROPERTIES OF SEED OF DIFFERENT GREENGRAM GENOTYPES AGAINST PULSE BRUCHID

4.2.1 Physical Parameters

The seed of twelve greengram genotypes under study were thoroughly examined for various physical parameters *viz.,* seed colour, surface texture, shape, length, width, length width ratio, seed coat hardness and 100 seed weight and the results are discussed below:

4.2.1.1 Seed Colour: Seed colour is an important criteria for characterizing the greengram genotypes and the colour of genotypes varies from dark green, green, light green, olive green to light olive green. LGG-407, LGG-574, LGG-586, LGG-607 and TM-92-2 had green, LGG-450, LGG-460, LGG-595 and WGG-42 had dark green, GGG-1 showed olive green, LGG-610 exhibited light green, while PM-5 had light olive green coloured seed (Table 4.11). From the data, it is evident that seed with light colour shades *i.e.*, olive green or light green colour are not preferred for egg laying by bruchids when compared to green and dark green colour. However, no reports were available on influence of seed colour on bruchid infestation in greengram. Nisar *et al.* (2008) reported high degree of variation in seed coat colour of pea germplasm. Ghafoor *et al.* (2001) evaluated 484 accessions of blackgram for qualitative traits and stated that small variation was observed for seed colour and spots on seed coat. Great diversity for phenotypic traits including pod colour, seed colour, seed mosaic and seed luster was observed in country bean which effected the bruchid infestation (Thomas *et al.*, 2002). In soybean, varietal characterization was made by Gaurav (1998) and significant variation among cultivars was observed for seed morphological traits like seed colour.

4.2.1.2 Seed Surface: The greengram genotypes LGG-407, LGG-450, LGG-574, LGG-586, TM-92-2 and WGG-42 had smooth seed surface which was much preferred by *C. chinensis*. The genotypes GGG-1, LGG-595, LGG-607, LGG-610 and PM-5 had rough seed surface, while LGG-460 had wrinkled seed surface, which can be considered

Table 4.11 Physical parameters of different greengram genotypes

Genotypes	Seed colour	Seed surface texture	Seed shape	Seed length (mm)	Seed width (mm)	Seed length width ratio	Seed coat hardness (%)	100 seed weight (g)
GGG-1	Olive green	Rough	Globose	4.27^{b}	3.70^{a}	1.15^{f}	57.33 $(49.20)^{h}$	4.00^{b}
LGG-407	Green	Smooth	Ovoid	4.10^{c}	3.26^{cd}	1.26^{bcd}	83.67 $(66.14)^{c}$	3.14^{e}
LGG-450	Dark green	Smooth	Cylindrical	4.22^{b}	3.21^{de}	1.32^{a}	71.33 $(57.61)^{de}$	3.23^{de}
LGG-460	Dark green	Wrinkled	Ovoid	4.25^{b}	3.25^{cd}	1.31^{ab}	91.00 $(72.53)^{b}$	3.51^{c}
LGG-574	Green	Smooth	Ovoid	3.95^{ef}	3.18^{de}	1.24^{cde}	62.00 $(51.92)^{g}$	3.14^{e}
LGG-586	Green	Smooth	Cylindrical	3.79^{g}	3.09^{f}	1.23^{cde}	68.33 $(55.73)^{ef}$	3.14^{e}
LGG-595	Dark green	Rough	Ovoid	4.00^{de}	3.32^{c}	1.20^{def}	83.67 $(66.14)^{c}$	3.27^{de}
LGG-607	Green	Rough	Cylindrical	3.90^{f}	3.15^{ef}	1.24^{cde}	65.33 $(53.91)^{fg}$	3.34^{d}
LGG-610	Light green	Rough	Ovoid	4.12^{c}	3.47^{b}	1.19^{ef}	66.33 $(54.51)^{fg}$	3.66^{c}
PM-5	Light olive green	Rough	Oblong	4.77^{a}	3.77^{a}	1.26^{abc}	96.00 $(79.10)^{a}$	4.87^{a}
TM-92-2	Green	Smooth	Ovoid	4.06^{cd}	3.29^{c}	1.24^{cde}	75.33 $(60.20)^{d}$	3.30^{de}
WGG-42	Dark green	Smooth	Ovoid	4.26^{b}	3.32^{c}	1.28^{abc}	74.33 $(59.54)^{d}$	3.21^{de}
Mean	-	-	-	4.14	3.34	1.24	74.56 (60.54)	3.48
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm ±	-	-	-	0.05	0.04	0.02	0.88	0.05
C.D. (5%)	-	-	-	0.14	0.12	0.05	2.56	0.16
C.V. (%)	-	-	-	2.05	2.07	2.46	2.51	2.70

Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significant different

as resistance character of greengram genotypes (Table 4.11). The results are in concurrence with that of Satyavir (1980) and Singhal and Singh (1985) who opined that smooth seed were much preferred for oviposition. Shafique and Ahmad (2005b) found that preference of the bruchid was less and less number of eggs were laid on wrinkled and black seeded genotypes. Seed with wrinkled seed coat and dark colour affected the beetle development and seemed to be less preferred than smooth, plumpy and white colour seed in chickpea. Shaheen (2006) also reported that the cultivars with hard, rough, wrinkled and thick seed coat were more resistant when compared with those having smooth, soft and thin seed coat.

4.2.1.3 Seed Shape: The seed shape of LGG-407, LGG-460, LGG-574, LGG-595, LGG-610, TM-92-2 and WGG-42 was ovoid, LGG-450, LGG-586 and LGG-607 was cylindrical, GGG-1 was globose and PM-5 was oblong (Table 4.11). The results showed that the genotypes with oblong and globose seed shape recorded lesser number of eggs when compared to cylindrical and ovoid shaped seed containing genotypes. Hence, it can be conferred that oblong and globose seed shape might be less preferred by the pulse bruchid for egg laying which leads to the less adult emergence and subsequently lower seed damage.

4.2.1.4 Seed Length, Width, Length Width Ratio (mm): Seed length ranged from 3.79 mm to 4.77 mm with maximum (4.77 mm) in PM-5 and minimum (3.79 mm) in LGG-586. Similarly, seed width differed significantly among the genotypes which ranged from 3.09 mm to 3.77 mm, with maximum (3.77 mm) in PM-5 and minimum (3.09 mm) in LGG-586. The seed length width ratio ranged from 1.15 to 1.32 with maximum (1.32) in LGG-450 followed by LGG-460 (1.31) and PM-5 (1.26) and minimum in GGG-1 (1.15) followed by LGG-610 (1.19) and LGG-595 (1.20) (Table 4.11 and Fig. 4.10). The present results clearly indicated that the genotypes with more length, width and length width ratio recorded less egg count, more development period and less seed weight loss and *vice-versa*. However, the influence of seed length or width on preference of pulse bruchid was not reported earlier.

Significant variation in seed length, width and length width ratio was observed among the greengram genotypes under study. Tripathi *et al.* (2013) earlier reported that the seed length, width and length width ratio varied significantly among the cowpea accessions.

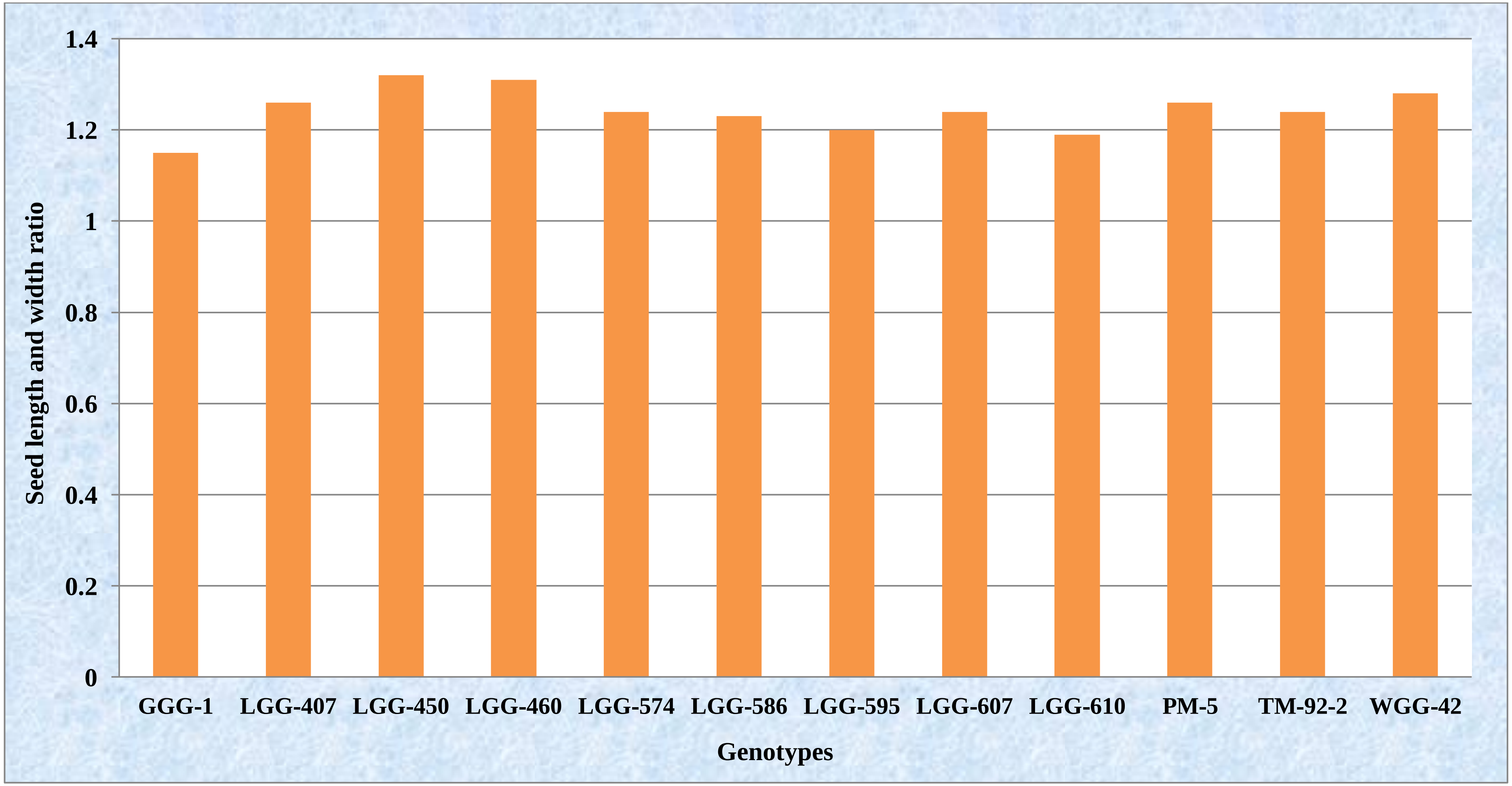


Figure 4.10. Seed length and width ratio of different greengram genotypes

4.2.1.5 Seed Coat Hardness (%): Seed coat hardness was measured based on percentage weight increase by water absorption which ranged from 57.33 to 96.00 per cent among the greengram genotypes. Lower the water absorption, higher is the seed coat hardness. Seed coat hardness was high in PM-5 (96.00 %), while it was low in GGG-1 (57.33 %) with significant differences among the genotypes (Table 4.11 and Fig. 4.11).

The data indicated that the genotypes with high seed coat hardness recorded less number of eggs, long mean development period and less weight loss and *vice-versa*. Thus the genotypes with more seed coat hardness are less preferred by pulse bruchid. The present results are in accordance with that of Rai and Singh (1989) who reported that yellow seed colour with smooth thin coats were more severely damaged than the small brown seed having hard coats in chickpea. Tripathi *et al.* (2013) reported that seed coat hardness ranged from 35.5 to 72 per cent among the cowpea accessions and showed significant influence on bruchid infestation.

4.2.1.6 100 Seed Weight (g): There was significant difference in 100 seed weight among the greengram genotypes. Weight of 100 seed or test weight of greengram genotypes was highest in PM-5 (4.87 g) and the lowest weight of 3.14 g was observed in LGG-407, LGG-574 and LGG-586 followed by WGG-42 (3.21 g), LGG-450 (3.23 g), LGG-595 (3.27 g) and TM-92-2 (3.30 g) (Table 4.11 and Fig. 4.12). It was observed that test weight had no significant influence on incidence of pulse bruchid. The present findings are in accordance with the results of Dabi *et al.* (1979) who reported that the weight of seed had no effect on the resistance or susceptibility of the cowpea varieties.

4.2.2 Biochemical parameters

The biochemical parameters *viz.*, protein, phenol and sugar contents were analysed initially and at eight months after storage in all the selected genotypes and the results were statistically analysed and presented here under.

4.2.2.1 Protein Content (mg g^{-1}): In fresh seed samples, the maximum (230.97 mg g^{-1}) protein content was found in WGG-42 which was found significantly superior over the other genotypes. Minimum protein content (184.87 mg g^{-1}) was recorded from PM-5 followed by GGG-1 (189.75 mg g^{-1}) and LGG-607 (188.42 mg g^{-1}) which were found on par with each other. (Table 4.12).

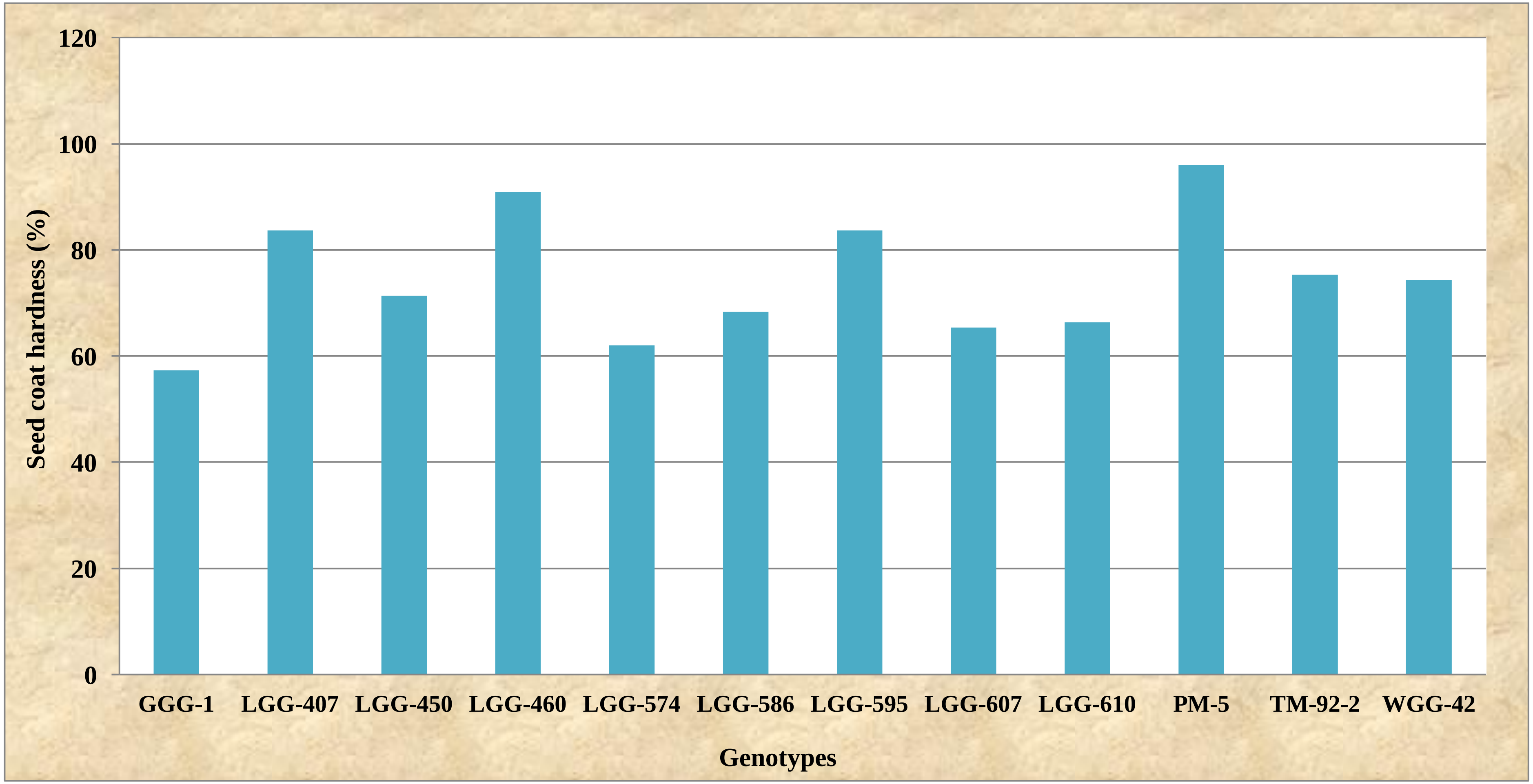


Figure 4.11. Seed coat hardness of different greengram genotypes

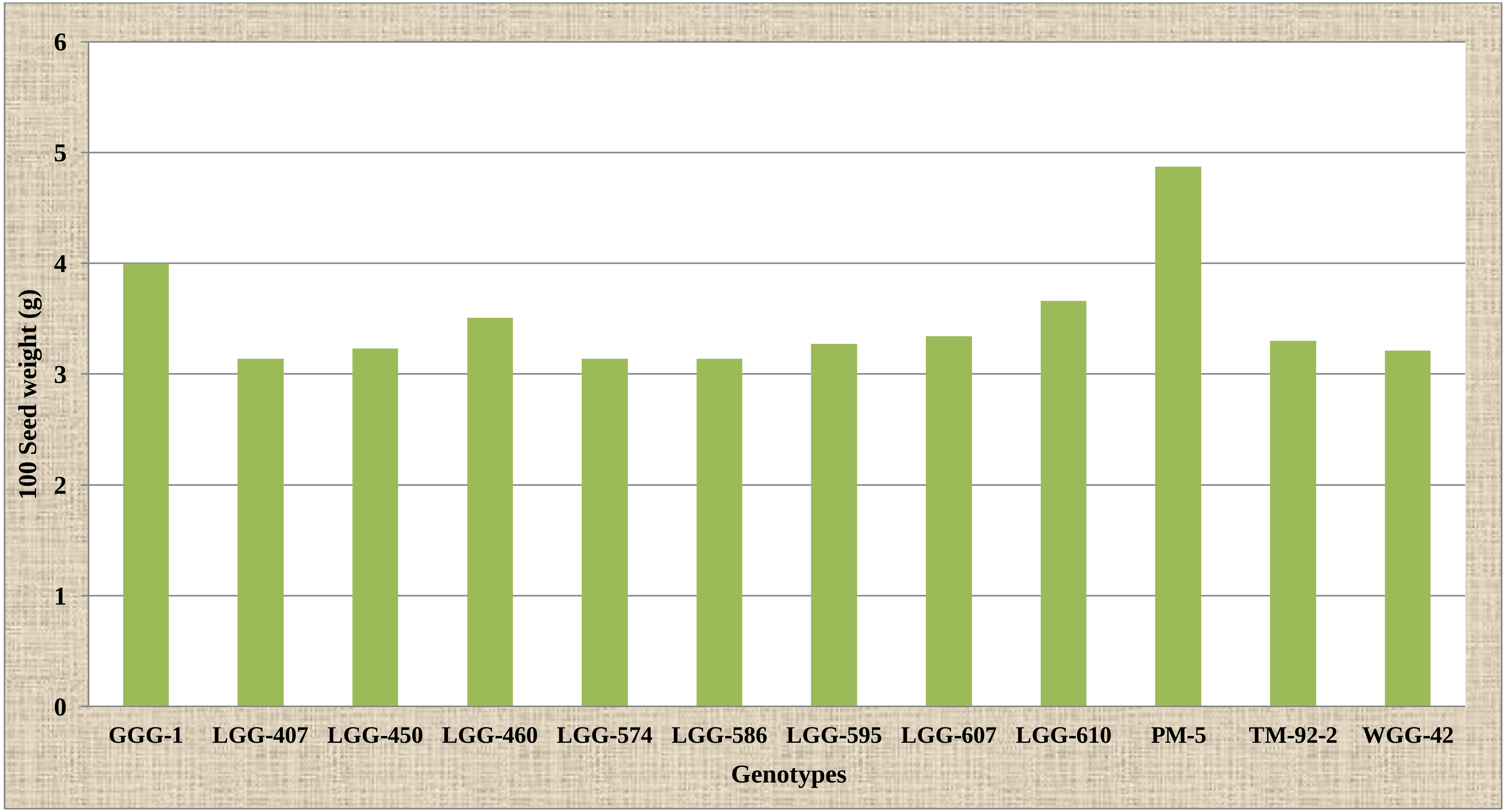


Figure 4.12. 100 seed weight of different greengram genotypes

Table 4.12 Biochemical parameters of greengram genotypes before and after infestation of pulse bruchid during the storage

Genotypes	Protein content (mg/g)		Phenol content (mg/g)		Total sugar content (mg/g)	
	Initial	After 8 months	Initial	After 8 months	Initial	After 8 months
GGG-1	189.75^{fg}	162.71^{e}	15.16^{c}	12.40^{c}	67.27^{f}	49.43^{f}
LGG-407	213.68^{bc}	188.42^{c}	7.44^{i}	4.45^{g}	76.38^{c}	64.49^{b}
LGG-450	225.20^{ab}	199.50^{b}	8.25^{h}	5.48^{f}	74.00^{cd}	54.98^{e}
LGG-460	196.84^{efg}	175.12^{d}	11.71^{e}	8.59^{e}	74.80^{cd}	61.72^{c}
LGG-574	210.58^{cd}	184.43^{c}	11.01^{f}	8.59^{e}	80.74^{b}	57.75^{d}
LGG-586	226.09^{a}	199.94^{b}	5.37^{j}	3.18^{h}	83.91^{ab}	66.47^{ab}
LGG-595	199.94^{def}	174.24^{d}	15.62^{bc}	11.94^{c}	68.45^{ef}	54.19^{e}
LGG-607	188.42^{fg}	163.60^{e}	16.20^{b}	14.13^{b}	71.23^{de}	54.19^{e}
LGG-610	213.24^{bc}	187.98^{c}	14.47^{d}	11.01^{d}	74.40^{cd}	59.73^{cd}
PM-5	184.87^{g}	164.49^{e}	19.08^{a}	16.20^{a}	62.51^{g}	45.86^{g}
TM-92-2	205.70^{cde}	179.56^{cd}	9.17^{g}	5.60^{f}	72.81^{cd}	62.11^{c}
WGG-42	230.97^{a}	215.90^{a}	5.14^{j}	1.91^{i}	85.10^{a}	68.06^{a}
Mean	207.11	182.99	11.55	8.62	74.30	58.25
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm ±	3.98	2.86	0.22	0.23	1.28	0.79
C.D. (5%)	11.63	8.34	0.64	0.66	3.75	2.31
C.V. (%)	3.33	2.71	3.31	4.53	2.99	2.36

Means in the same column showing similar alphabets are not significantly different

There were significant differences in the protein content in different greengram genotypes at eight months after storage. The protein content in seed among greengram genotypes ranged from 162.71 mg g^{-1} to 215.90 mg g^{-1}. The minimum protein content was recorded in GGG-1 (162.71 mg g^{-1}) followed by LGG-607 (163.60 mg g^{-1}) and PM-5 (164.49 mg g^{-1}) which were found to be at par with each other. While maximum protein content was recorded in WGG-42 (215.90 mg g^{-1}) even at eight months after storage (Table 4.12).

There was a considerable decrease in protein content in infested seed of all the greengram genotypes due to feeding of *C. chinensis*. The protein content highly decreased in infested seed of GGG-1 (14.25 %), while minimum reduction in protein content was recorded in WGG-42 (6.52 %) (Fig. 4.13). The genotypes having higher protein content were much preferred by *C. chinensis* in comparision to less protein content genotypes. Since, the genotypes with less protein content recorded less weight loss at eight months after storage.

The present findings are in accordance with the results of Reddy and Pushpamma (1986) who found that there was a decrease in protein content in pigeonpea, chickpea and greengram due to infestation of *C.chinensis*. Dudu *et al.* (1996) reported a slight decrease in protein content in groundnut from 24.5 to 23.4 % after nine months of storage, due to merchant beetle (*Oryzaephilus mercator*). Verma *et al.* (1999) also found that the low protein content rice varieties were less susceptible and *vice-versa* to lesser grain beetle. Rao and Verma (2003) studied the protein composition of 20 pea accessions for preference of *C. chinensis* and reported that pea accessions with high protein content recorded higher infestation. Raja *et al.* (2004) observed that there was significant decrease in protein content (%) with increase in the level of bruchid infestation on greengram seed. Saxena and Saxena (2011) noticed an increase in weevilisation with increased protein content in chick pea. In contrast Chakraborty *et al.* (2004) reported that the protein content of seed had no influence on susceptibility of pulse beetle in mungbean.

4.2.2.2 Phenol Content (mg g^{-1}): The phenol content ranged from 5.14 to 19.08 mg g^{-1} among the greengram genotypes in initial seed samples. The maximum phenol content (19.08 mg g^{-1}) was observed in PM-5, while the minimum phenol content (5.14 mg g^{-1}) was observed in WGG-42 followed by LGG-586 (5.37 mg g^{-1}) with significant differences among the genotypes (Table 4.12).

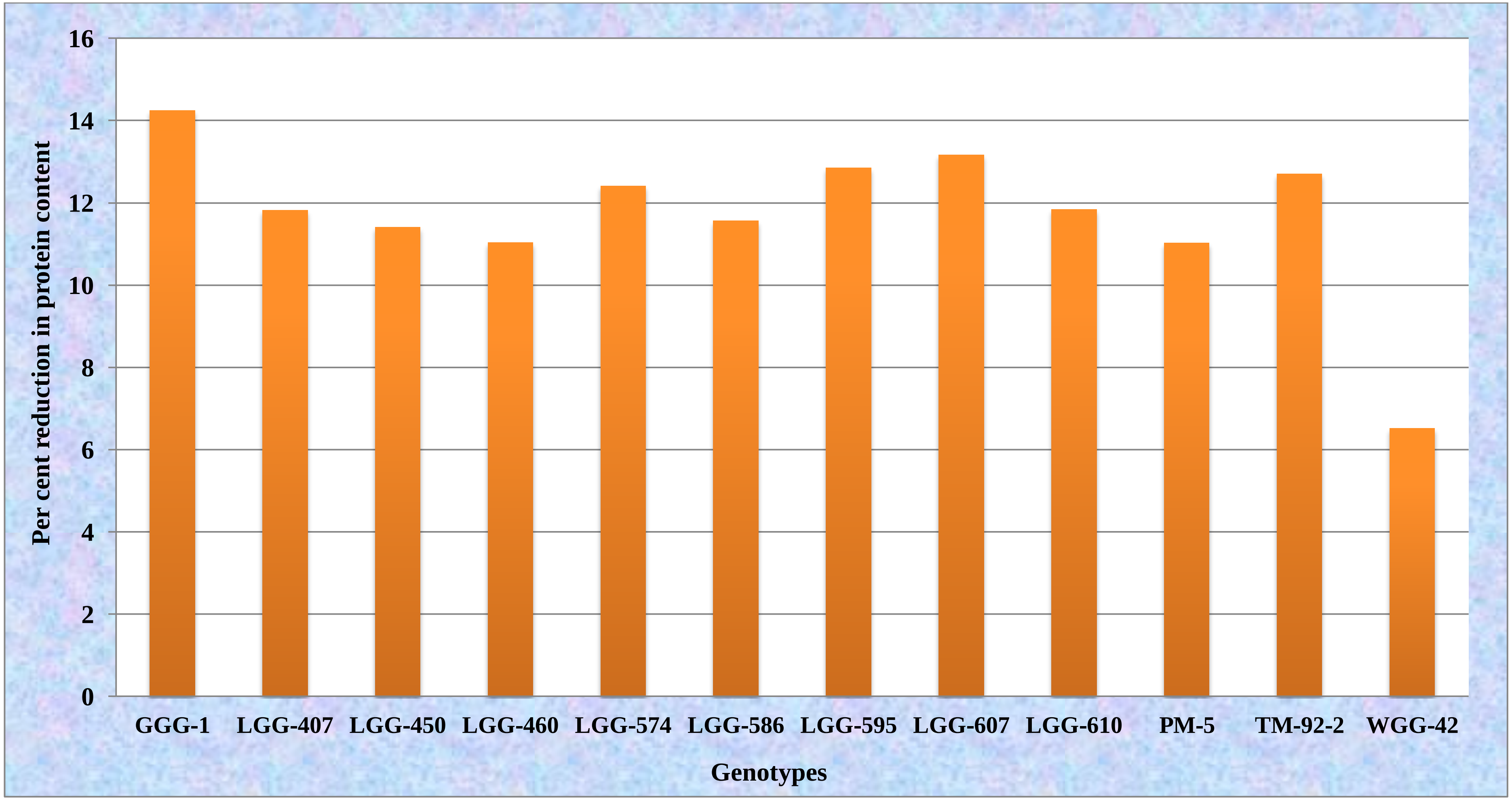


Figure 4.13. Per cent reduction in protein content in different greengram genotypes over 8 months of storage

At eight months after infestation, the phenol content in seed among the greengram genotypes varied from 1.91 mg $g^{-1}$to 16.20 mg $g^{-1}$with significant differences. PM-5 (16.20 mg g^{-1}) recorded the maximum phenol content, while the minimum was recorded in WGG-42 (1.91 mg g^{-1}) which was significantly low among all the genotypes. (Table 4.12).

The overall assessment of phenol content in fresh as well as infested seed showed that there was considerable reduction in phenol content after bruchid infestation with significant differences among the various genotypes. The maximum reduction in phenol content was recorded from WGG-42 (62.84 %), while minimum reduction was recorded from PM-5 (15.09 %) (Fig. 4.14).

The results clearly indicated that the genotypes with high phenol content prolonged the development period of bruchid together with less seed damage. Hence, from the data it was proved that high phenol content may confer resistance against bruchids. The phenols may affect the metabolic enzymes in insects as the phenol acts as antimetabolic factor and might have contributed to resistance mechanism or phenols may have inhibitory role on the development of *C. chinensis.* Thepresent findings are in consistency with those of Krishnananda (1972) concluded that susceptible varieties contained low quantity of phenols compared to the varieties resistant to jassids.Venugopal *et al*. (2000) noticed that higher amounts of non-protein anti-metabolites such as total phenols and orthodihydroxy phenols conferred resistance to bruchid attack in wild grain legume varieties. Patel *et al.* (2002) also found that phenol content of the different pulses prolonged the development period of *C. chinensis*. Ghosal *et al.* (2004) who observed retarded growth and development of *C. chinensis* on legume seed with high phenol content. Nasar *et al.* (2009) reported the presence of total free phenolics contributed resistance to pulse beetle during storage of faba bean. Divya *et al.* (2013b) stated that high phenol content in the accessions of horse gram was detrimental to the growth and development of *C. chinensis*, while high protein content, low phenols and thin seed coat of the test accessions favoured the successful development of bruchids.

4.2.2.3 Total Sugar Content (mg g^{-1}): Significant variation in total sugar content was noticed among different greengram genotypes. In fresh seed samples, maximum total sugar content (85.10 mg g^{-1}) was recorded in WGG-42 followed by LGG-586 (83.91 mg g^{-1}). Minimum total sugar content (62.51 mg g^{-1}) was recorded in PM-5 which was significantly inferior to all the other genotypes (Table 4.12).

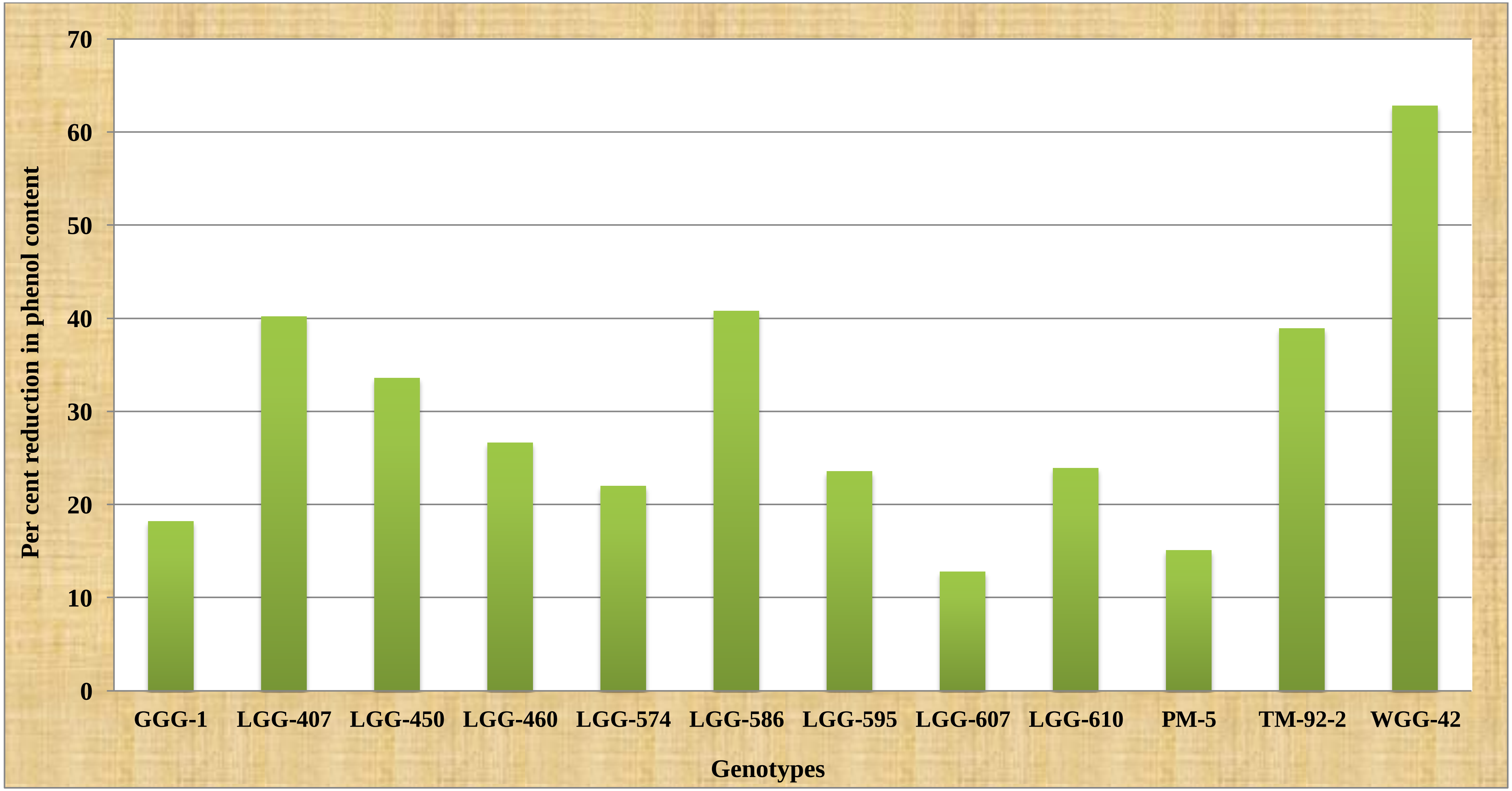


Figure 4.14. Per cent reduction in phenol content in different greengram genotypes over 8 months of storage

At eight months after infestation, the total sugar content in seed ranged from 45.86 mg g^{-1} to 68.06 mg g^{-1} with significant differences among the greengram genotypes. Minimum total sugar content (45.86 mg g^{-1}) was recorded in PM-5, while the maximum sugar content (68.06 mg g^{-1}) was recorded in WGG-42. (Table 4.12).

The total sugar content in fresh as well as infested seed showed that there was considerable reduction in their total sugar content after infestation. Sugar content in seed decreased to maximum extent in infested seed of LGG-574 (28.47 %), while minimum reduction was observed in TM-92-2 (14.69 %) (Fig. 4.15). The genotypes of greengram having higher sugar content were much preferred by *C. chinensis* in comparision to less sugar content genotypes, in the present study. The results are in harmony with that of Singh *et al.* (1982) reported that there was a increase in reducing sugars up to four months of storage (1325 mg of maltose/ 100 g of seed) which declined later in the fifth month (1085 mg of maltose/ 100 g of seed) due to bruchid infestation. Bhise *et al.* (1996) reported that the susceptible check, CSH 1 had the highest total sugar content, whereas the resistant variety, IS 5490 had the lowest total sugar content during the crop growth. Vijay (2000), who recorded slight decrease in total soluble sugar in maize and soybean after 15 months of storage.

4.2.3Correlation Analysis

The results of simple correlation analysis between the biological parameters of pulse bruchid and physico-chemical properties of seed are presented in Table 4.13. The correlation studies revealed that the eggs laying by bruchid exhibited highly significant positive correlation with protein content (r = 0.834), sugar content (r = 0.856), electrical conductivity (r = 0.934) and moisture content (r = 0.930), while it was highly significant and negative with 100 seed weight (r = -0.792) and phenol content (r = -0.955). Negative correlation was noticed between eggs laid / 100 seeds and seed coat hardness (r = -0.251) but it was non-significant. The present results are in agreement with the findings of Pankaj and Singh (2011) who reported that the seed characters such as seed coat thickness, colour and texture of seed coat had no significant influence on ovipositional preference by pulse bruchid on different pulse seeds. Somta *et al.* (2008) also observed non-significant role of seed coat thickness on oviposition.

Adult emergence exhibited highly significant positive correlation with protein content (r = 0.751), sugar content (r = 0.781), electrical conductivity (r = 0.811) and moisture content (r = 0.813), while highly significant negative correlation was observed

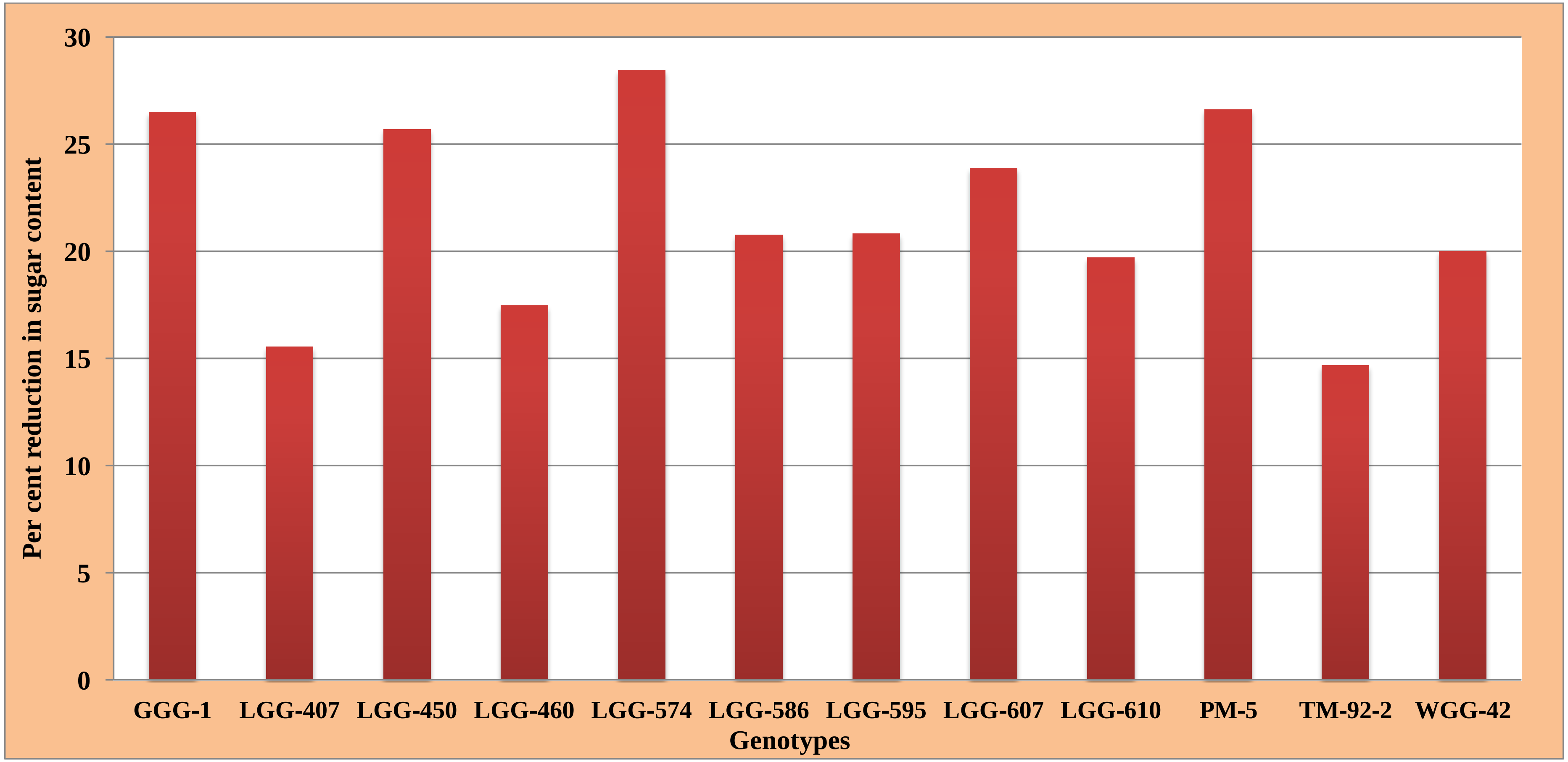


Figure 4.15. Per cent reduction in sugar content in different greengram genotypes over 8 months of storage

Table 4.13 Correlation analysis between biological parameters of pulse bruchid and physico-chemical properties of seed

Parameters	Seed coat hardness	100 seed weight	Protein content	Phenol content	Sugar content	Electrical conductivity	Moisture content
Number of eggs laid/ 100 seed	-0.251	-0.792**	0.834**	-0.955**	0.856**	0.934**	0.930**
Adult emergence	-0.290	-0.843**	0.751**	-0.905**	0.781**	0.811**	0.813**
Mean development period	0.263	0.723**	-0.974**	0.941**	-0.873**	-0.911**	-0.856**
Growth index	-0.071	-0.600*	0.832**	-0.919**	0.794**	0.932**	0.954**

**Significant at 1 % level
*Significant at 5 % level

Table 4.14 Regression analysisbetween biological parameters of pulse bruchid and physico-chemical properties of seed

Parameters	Regression analysis	R^2 value (%)
Number of eggs	$Y=2.52-2.825 X_1-0.507 X_2+16.426 X_3-5.527 X_4+7.238 X_5+0.456 X_6+0.273 X_7$	87.19*
Adult emergence	$Y=23.729-18.618 X_1-3.088 X_2+84.393 X_3-29.932 X_4+37.706 X_5+2.263 X_6+1.366 X_7$	65.81*
Mean development period	$Y=36.442+5.458 X_1+0.853 X_2-35.296 X_3+10.029 X_4-13.58 X_5-0.819 X_6-0.464 X_7$	82.98*
Growth index	$Y=0.188-0.313 X_1-0.151 X_2+6.411 X_3-2.082 X_4+2.628 X_5+0.178 X_6+0.11 X_7$	86.82*

*Significant at 5 % level (P=0.005)

X_1 - Seed coat hardness
X_2 -100 seed weight
X_3 - Protein content (mg/g)
X_4 - Phenol content (mg/g)
X_5 - Sugar content (mg/g)
X_6 - Electrical conductivity
X_7 - Moisture content

with 100 seed weight (r = -0.843) and phenol content (r = -0.905). Non significant negative correlation was noticed between adult emergence and seed coat hardness (r = -0.290). The results are in concurrence with the reports of Srinivas (1980) who found a positive significant correlation between protein content in grain and the number of *C. maculatus* adults emerged in different redgram varieties.

In contrast to egg laying and adult emergence, the mean development period exhibited highly significant positive correlation with 100 seed weight (r = 0.723) and phenol content (r = 0.941), while highly significant negative correlation with protein content (r = -0.974), sugar content (r = -0.873), electrical conductivity (r = -0.911) and moisture content (r = -0.856). Non significant positive correlation was noticed between mean development period and seed coat hardness (r = -0.290).

Growth index exhibited highly significant positive correlation with protein content (r = 0.832), sugar content (r = 0.794), electrical conductivity (r = 0.932) and moisture content (r = 0.954), while highly significant negative association was noticed with phenol content (r = -0.919) and significant negative correlation was observed with 100 seed weight (r = -0.600). There was a negative correlation between growth index and seed coat hardness (r = -0.071) which was non-significant. The results are in corroboration with that of Soumia *et al.* (2015) who reported that the biochemical parameters such as phenol and tannin contents had negative relation, while crude protein, soluble protein and starch contents had positive relation with growth index. Anuradha *et al.* (1989) reported positive correlation between protein content of kernels and susceptibility index of sitotroga in rice.

4.2.4 Regression Analysis

Multiple linear regression analysis between growth parameters of pulse bruchid and physico-chemical properties of different greengram genotypes (Table 4.14) revealed that all the physical and chemical properties together *viz.*, seed coat hardness, 100 seed weight, protein content, phenol content, total sugar content, electrical conductivity and moisture content were responsible for 87.19 percent variation in egg laying *i.e.*, number of eggs/ 100 seed by pulse bruchid. Similarly, all the properties together were causing significant variation in adult emergence (65.81 %), mean development period (82.98 %) and growth index (86.82 %) of pulse bruchid. However, there was no significant influence of individual properties on growth parameters of pulse bruchid.

4.3 EVALUATION ON THE EFFECTIVENESS OF ECO-FRIENDLY MATERIAL AS SEED PROTECTANTS AGAINST PULSE BRUCHID IN GREENGRAM

The efficacy of different eco-friendly material as seed protectants against pulse bruchid was evaluated by treating the seed of greengram variety, LGG-460. Two pairs of freshly emerged adults were released into each cloth bag containing one kg of treated greengram seed. The data on incidence of bruchid and seed parameters was recorded initially and upto eight months after treatment at monthly interval and was statistically analysed and the results are discussed below:

4.3.1 Influence of Different Seed Protectant Materials on Biological Parameters of Pulse Bruchid

The data recorded at monthly interval upto eight months of storage on various biological parameters of pulse bruchid *i.e.*,number of eggs laid, adult emergence, seed weight loss and adult mortality were statistically analysed and the results are discussed below:

4.3.1.1 Number of Eggs/ 100 seed: The results indicated that all the treatments were significantly superior to control in inhibiting the egg laying by pulse bruchid. The mean number of eggs was 2.25/ 100 seed during first month which increased progressively over the period of storage upto 58.88/ 100 seed after eighth month (Table 4.15 and Fig. 4.16).

During the first month, the number of eggs varied from 0.00 to 7.00/ 100 seeds among the different treatments. The number of eggs was significantly low in the coconut oil and malathion dust (0.00/ 100 seed), while the number of eggs was significantly high in untreated control (7.00/ 100 seed). Same trend was observed during the subsequent months of storage with significant differences among the treatments.

At the end of storage period (8th month), number of eggs laid by pulse bruchid varied from 0.00 (coconut oil and malathion dust) to 160.67 (untreated control) among various treatments with significant differences. Turmeric powder and fly ash registered the highest number of eggs among the different seed protectants evaluated(133.00/ 100 seed and 128.67/ 100 seed respectively), but were superior to untreated control (160.67/ 100 seed) in reducing the egg laying by pulse bruchid (Table 4.15).

Table 4.15 Effect of different seed protectant material on egg laying by pulse bruchid in stored greengram seedafter artificial infestation

Treatments	Number of eggs/ 100 seeds								
	1 MAR	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
Turmeric powder @ 20 g kg^{-1}	5.00 (2.44)^{b}	21.67 (4.76)^{b}	32.67 (5.80)^{a}	52.67 (7.32)^{b}	72.67 (8.58)^{b}	98.00 (9.95)^{b}	117.33 (10.88)^{b}	133.00 (11.58)^{b}	**66.63 (8.23)^{b}**
Neem leaf powder @ 25 g kg^{-1}	2.00 (1.73)^{e}	4.67 (2.38)^{e}	8.33 (3.05)^{e}	11.67 (3.56)^{e}	15.00 (4.00)^{d}	20.67 (4.65)^{e}	30.00 (5.56)^{d}	36.67 (6.12)^{d}	**16.13 (4.14)^{e}**
Neem seed kernel powder @ 5 g kg^{-1}	3.00 (2.00)^{d}	13.33 (3.78)^{d}	18.67 (4.40)^{d}	25.00 (5.10)^{d}	62.00 (7.94)^{c}	83.00 (9.16)^{d}	104.33 (10.26)^{c}	122.33 (11.11)^{c}	**53.96 (7.41)^{d}**
Coconut oil @ 5ml kg^{-1}	0.00 (1.00)^{f}	0.00 (1.00)^{f}	0.00 (1.00)^{g}	0.00 (1.00)^{g}	0.00 (1.00)^{f}	0.00 (1.00)^{g}	0.00 (1.00)^{f}	0.00 (1.00)^{f}	**0.00 (1.00)^{g}**
Inert dust @ 5 g kg^{-1}	2.00 (1.73)^{e}	4.00 (2.24)^{e}	6.33 (2.71)^{f}	8.33 (3.05)^{f}	9.67 (3.27)^{e}	12.33 (3.65)^{f}	16.00 (4.12)^{e}	22.67 (4.86)^{e}	**10.17 (3.34)^{f}**
Fly ash @ 10 g kg^{-1}	4.00 (2.24)^{c}	19.33 (4.51)^{c}	30.33 (5.60)^{c}	47.67 (6.97)^{c}	63.33 (8.02)^{c}	90.00 (9.54)^{c}	107.33 (10.41)^{c}	128.67 (11.39)^{bc}	**61.33 (7.89)^{c}**
Malathion dust @ 1 g kg^{-1}	0.00 (1.00)^{f}	0.00 (1.00)^{f}	0.00 (1.00)^{g}	0.00 (1.00)^{g}	0.00 (1.00)^{f}	0.00 (1.00)^{g}	0.00 (1.00)^{f}	0.00 (1.00)^{f}	**0.00 (1.00)^{g}**
Untreated control	7.00 (2.82)^{a}	25.00 (5.10)^{a}	38.33 (6.27)^{a}	57.00 (7.61)^{a}	82.67 (9.14)^{a}	112.33 (10.65)^{a}	136.00 (11.70)^{a}	160.67 (12.71)^{a}	**77.38 (8.85)^{a}**
Mean	2.25 (1.87)	8.29 (3.10)	12.75 (3.73)	18.71 (4.45)	29.08 (5.37)	39.79 (6.20)	49.21 (6.87)	58.88 (7.47)	**27.37 (5.23)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.06	0.06	0.05	0.08	0.10	0.10	0.11	0.13	**0.06**
C.D. (5%)	0.17	0.19	0.16	0.25	0.30	0.29	0.34	0.39	**0.19**
C.V. (%)	5.12	3.52	2.55	3.29	3.22	2.70	2.89	2.98	**2.11**

MAR: Months after release
Figures in parenthesis are square root transformed values
Means in the same column showing similar alphabets are not significantly different

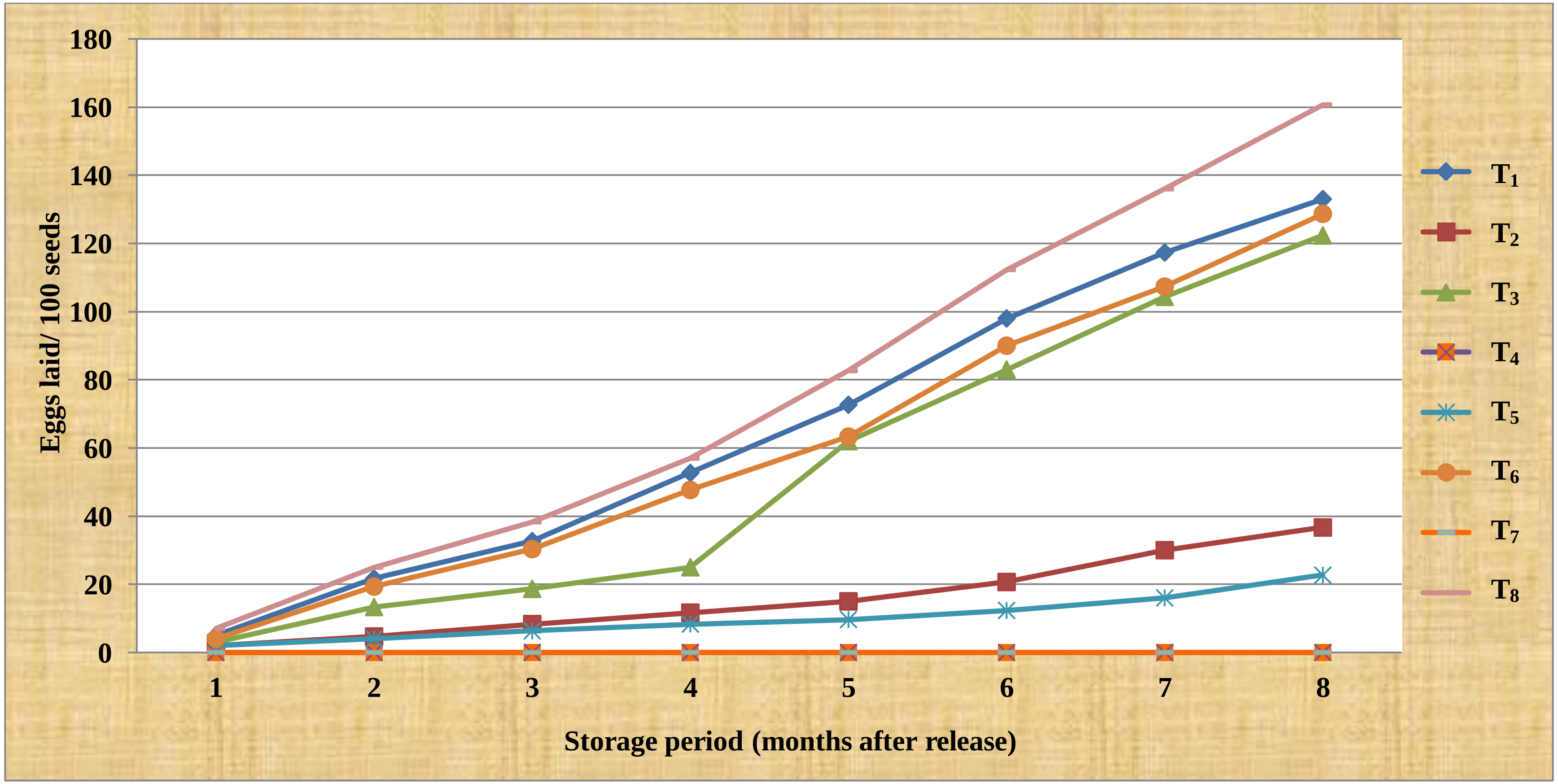


Figure 4.16. Effect of different seed protectant material on egg laying by pulse bruchid in stored greengram after artificial infestation

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}
T_8 - Untreated control

The pooled data over eight months indicated that the seed treatment with coconut oil and malathion dust were proved superior which recorded no infestation (0.00 number/ 100 seed) throughout the period of storage. Turmeric powder and fly ash treatments were found to be highly preferred for egg laying by pulse bruchid with significantly highest number of eggs among the different seed protectants (66.63/ 100 seed and 61.33/ 100 seed, respectively). The data clearly indicated that coconut oil @ 5 ml kg^{-1} seed was highly effective similar to the insecticide check *i.e.*, seed treatment with malathion dust @ 1 g kg^{-1} seed. The other treatments *i.e.,* use of inert dust @ 5 g kg^{-1} seed (10.17/ 100 seed) and neem leaf powder @ 25 g kg^{-1} (16.13/ 100 seed) as grain protectants were also found effective in reducing egg laying by bruchid.

Nagangouda *et al*. (2012) reported that the number of eggs laid by bruchid decreased significantly as the dose of malathion increased. Decreased fecundity by bruchids on pulse seed treated with different vegetable oils (edible, non-edible and hair oils) has been reported by several earlier workers (Singh *et al.,* 1978., Messina and Renwich, 1983., Sujatha and Punnaiah, 1985., Yadav, 1985., Babu *et al*., 1989., Kachare *et al.*, 1994., Singh *et al.,* 1994., Pacheco *et al.*, 1995., Khanna, 1995., Reddy *et al.*, 1999., Mishra, 2000., Bhatanagar *et al*., 2001., Singh, 2003., Raghvani and Kapadia, 2003 and Jagjeet *et al.*, 2005). These oils had adverse effect on oviposition and showed significant repellent or ovipositional deterrent effect on egg laying by bruchids up to six months and resulted in low fecundity on treated seed. Ovicidal action of neem oil against pulse beetle was reported by Khaire *et al.* (1993), Vir (1994) and Raghuraman and singh (1997).

4.3.1.2 Adult Emergence (%): The data on mean adult emergence revealed that all the seed protectant treatments were significantly superior over untreated control in suppressing the emergence of adults. The mean adult emergence increased progressively throughout the storage period with wide variation from first month (25.62 %) to eighth month (43.82 %), irrespective of the seed protectants used (Table 4.16 and Fig. 4.17).

During the first month, the adult emergence varied from 0.00 to 50 % among the different treatments. The adult emergence was nil (0.00 %) in the coconut oil andmalathion dust, while the adult emergence was significantly high in untreated control (50 %). Similar trend was noticed during the subsequent months of storage with significant differences among the treatments.

Table 4.16 Effect of different seed protectant material on adult emergence (%) of pulse bruchid in stored greengram seedafter artificial infestation

Treatments	Adult emergence (%)								
	1 MAR	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
Turmeric powder @ 20 g kg^{-1}	46.67 (43.06)^{a}	49.74 (44.83)^{b}	51.71 (45.96)^{ab}	52.17 (46.23)^{a}	53.88 (47.21)^{ab}	55.99 (48.42)^{ab}	58.15 (49.67)^{a}	64.53 (53.43)^{a}	54.10 (47.34)^{a}
Neem leaf powder @ 25 g kg^{-1}	16.67 (14.99)^{d}	23.33 (28.84)^{d}	27.78 (31.74)^{d}	34.34 (35.86)^{c}	40.12 (39.28)^{d}	46.74 (43.11)^{d}	47.95 (43.81)^{d}	53.96 (47.25)^{c}	36.36 (37.05)^{c}
Neem seed kernel powder @ 5 g kg^{-1}	33.33 (35.25)^{c}	37.26 (37.59)^{c}	40.92 (39.74)^{c}	43.97 (41.52)^{b}	49.46 (44.67)^{c}	50.20 (45.10)^{c}	51.75 (45.98)^{c}	52.58 (46.46)^{c}	44.93 (42.08)^{b}
Coconut oil @ 5ml kg^{-1}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{d}
Inert dust @ 5 g kg^{-1}	16.67 (14.99)^{d}	25.00 (29.99)^{d}	26.19 (30.54)^{d}	31.94 (34.33)^{c}	37.78 (37.89)^{d}	45.94 (42.65)^{d}	47.90 (43.78)^{d}	53.03 (46.72)^{c}	35.56 (36.55)^{c}
Fly ash @ 10 g kg^{-1}	41.67 (39.98)^{b}	48.33 (44.02)^{ab}	49.42 (44.65)^{b}	51.28 (45.71)^{a}	53.63 (47.06)^{b}	53.84 (47.19)^{b}	54.22 (47.50)^{b}	60.81 (51.22)^{b}	51.65 (45.93)^{a}
Malathion dust @ 1 g kg^{-1}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{d}
Untreated control	50.00 (44.98)^{a}	53.28 (46.87)^{a}	55.48 (48.13)^{a}	55.72 (48.27)^{a}	57.12 (49.07)^{a}	57.69 (49.41)^{a}	59.29 (50.33)^{a}	65.63 (54.10)^{a}	56.78 (48.87)^{a}
Mean	25.62 (24.16)	29.62 (29.02)	31.44 (30.10)	33.68 (31.49)	36.50 (33.15)	38.80 (34.48)	39.91 (35.12)	43.82 (37.40)	34.92 (32.23)
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.
SEm ±	0.73	0.86	0.90	1.05	0.63	0.64	0.44	0.60	**0.97**
C.D. (5%)	2.18	2.57	2.68	3.16	1.88	1.93	1.33	1.79	**2.90**
C.V. (%)	5.21	5.11	5.15	5.79	3.28	3.24	2.18	2.77	**5.20**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different

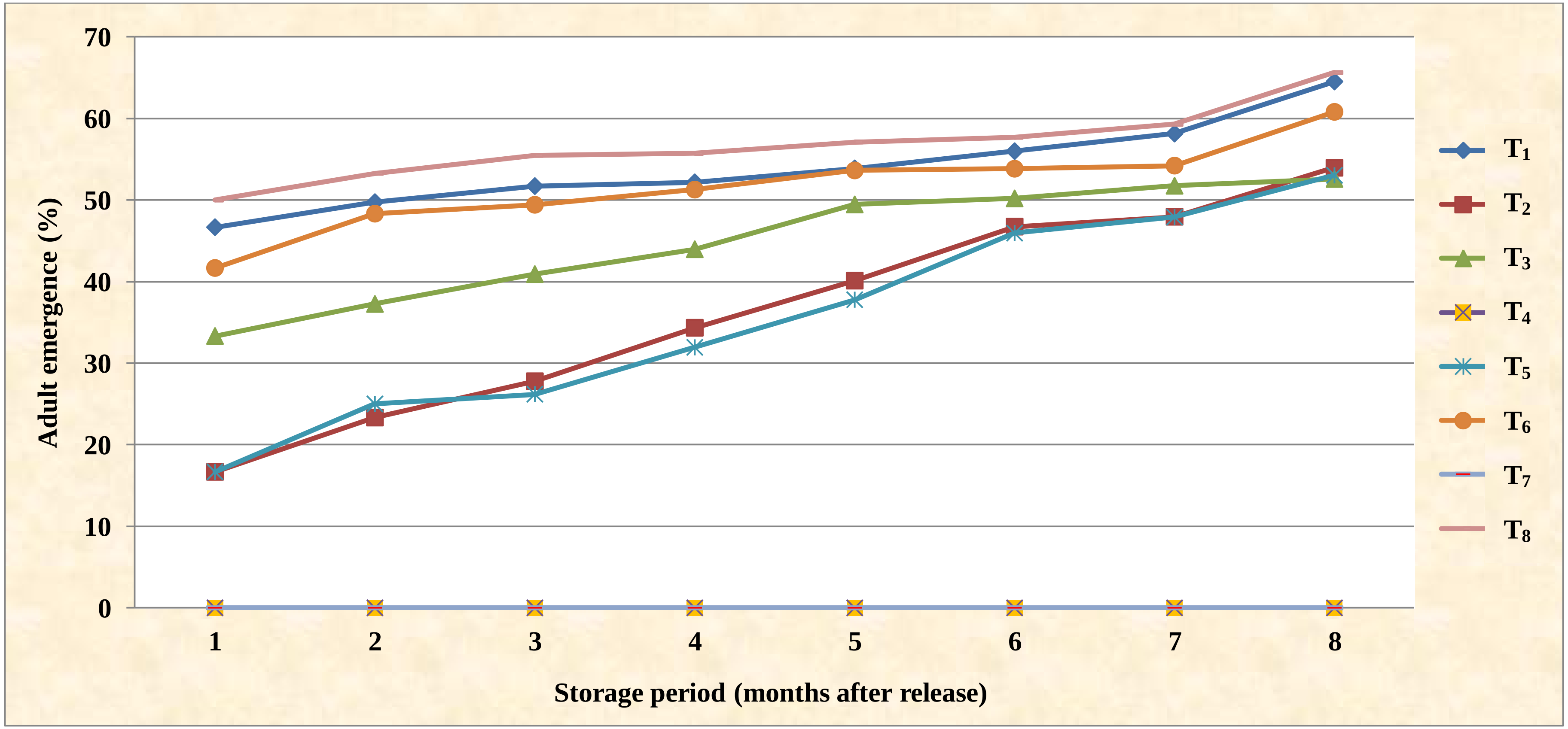


Figure 4.17. Effect of different seed protectant material on adult emergence (%) of pulse bruchid in stored greengram after artificial infestation

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}
T_8 - Untreated control

At eight months after storage, the adult emergence ranged from 0.00 % (coconut oil and malathion dust) (Plate 4.5 and Plate 4.6) to 65.63 % (untreated control) (Plate 4.7) among various treatments with significant differences. Turmeric powder and fly ash registered the highest adult emergence (64.53 % and 60.81 %, respectively) among the different seed protectants evaluated but were superior to untreated control (65.63 %).

The pooled data on adult emergence indicated that the use of seed protectants significantly reduced the adult emergence over the untreated control. The seed protectant treatments such as turmeric powder (54.10 %) and fly ash (51.65 %) recorded higher mean adult emergence, but significantly superior over the untreated control (56.78 %) in reducing the adult emergence. The adult emergence was nil from coconut oil and malathion dust treated seed as there was no egg laying due to complete mortality of adults (Table 4.16). The mixing of coconut oil smoothened the seed surface so that beetle could not proliferate on smooth seed coat. Thus the present study is in conformity with the findings of above authors.

Efficacy of different plant materials as seed protectants (neem leaf powder, black pepper seed powder and clove powder *etc.*) in reducing the emergence of adult bruchids on pulse seed up to four months of storage was reported previously by Gill and Singh (2012), Devi and Devi (2013), Neog and Singh (2013) and Patro and Patro (2014). Several earlier workers opined that oils of neem, karanj, coconut, groundnut, castor, mustard, soybean, sesame *etc.* at various concentrations as surface protectants caused significant reduction in emergence of adult bruchids on different pulse grains up to three to nine months after seed treatment in storage (Lakhanpal *et al*., 1995., Reddy *et al*., 1999., Singh, 2003 and Sreekanth *et al*., 2011a).

4.3.1.3 Adult Mortality (%): The data on mean adult mortality revealed that all the seed protectants were significantly superior to control upto eight months of storage. The mortality of adults decreased progressively over the period of storage, for all the treatments evaluated (Table 4.17 and Fig. 4.18). The mean adult mortality ranged from 71.77 % during first month to 51.63 % after 8 months of storage.

Table 4.17 Effect of different seed protectant material on adult mortality (%) of pulse bruchid in stored greengram seedafter artificial infestation

Treatments	Adult mortality (%)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	38.09 (37.99)[e]	24.88 (29.91)[d]	22.61 (28.34)[d]	18.69 (25.60)[d]	18.41 (25.36)[d]	16.99 (24.33)[f]	15.63 (23.27)[f]	11.59 (19.88)[f]	**20.86 (27.16)[f]**
Neem leaf powder @ 25 g kg^{-1}	97.93 (81.70)[b]	94.11 (76.83)[b]	90.37 (71.90)[b]	87.37 (69.16)[b]	85.85 (67.88)[b]	84.21 (66.56)[c]	81.18 (64.28)[c]	70.55 (57.11)[c]	**86.45 (68.37)[c]**
Neem seed kernel powder @ 5 g kg^{-1}	90.29 (71.83)[c]	84.12 (66.53)[c]	76.96 (61.29)[c]	74.44 (59.73)[c]	46.03 (42.66)[c]	37.42 (37.70)[d]	33.90 (35.59)[d]	32.74 (34.89)[d]	**59.49 (50.46)[d]**
Coconut oil @ 5ml kg^{-1}	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	**100.00 (89.96)[a]**
Inert dust @ 5 g kg^{-1}	97.85 (81.66)[b]	94.86 (76.92)[b]	91.22 (72.74)[b]	90.33 (71.85)[b]	89.35 (70.92)[b]	87.58 (69.34)[b]	85.41 (67.52)[b]	81.61 (64.58)[b]	**89.78 (71.32)[b]**
Fly ash @ 10 g kg^{-1}	50.00 (44.98)[d]	29.76 (32.99)[d]	23.44 (28.87)[d]	22.37 (28.17)[d]	21.23 (27.42)[d]	20.76 (27.10)[e]	19.19 (25.97)[e]	16.53 (23.97)[e]	**25.41 (30.26)[e]**
Malathion dust @ 1 g kg^{-1}	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	100.00 (89.96)[a]	**100.00 (89.96)[a]**
Untreated control	0.00 (0.00)[f]	0.00 (0.00)[e]	0.00 (0.00)[e]	0.00 (0.00)[e]	0.00 (0.00)[e]	0.00 (0.00)[g]	0.00 (0.00)[g]	0.00 (0.00)[g]	**0.00 (0.00)[g]**
Mean	71.77 (62.26)	65.97 (57.89)	63.08 (55.38)	61.65 (54.30)	57.61 (51.77)	55.87 (50.62)	54.41 (49.57)	51.63 (47.54)	**53.55 (53.44)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	1.38	1.55	0.81	1.04	1.35	0.75	0.61	0.35	**1.04**
C.D. (5%)	4.14	4.65	2.44	3.11	4.04	2.25	1.82	1.04	**3.11**
C.V. (%)	3.84	4.64	2.55	3.30	4.51	2.57	2.12	3.38	**3.37**

MAR: Months after release

Figures in parenthesis are arc sine transformed values

Means in the same column showing similar alphabets are not significantly different

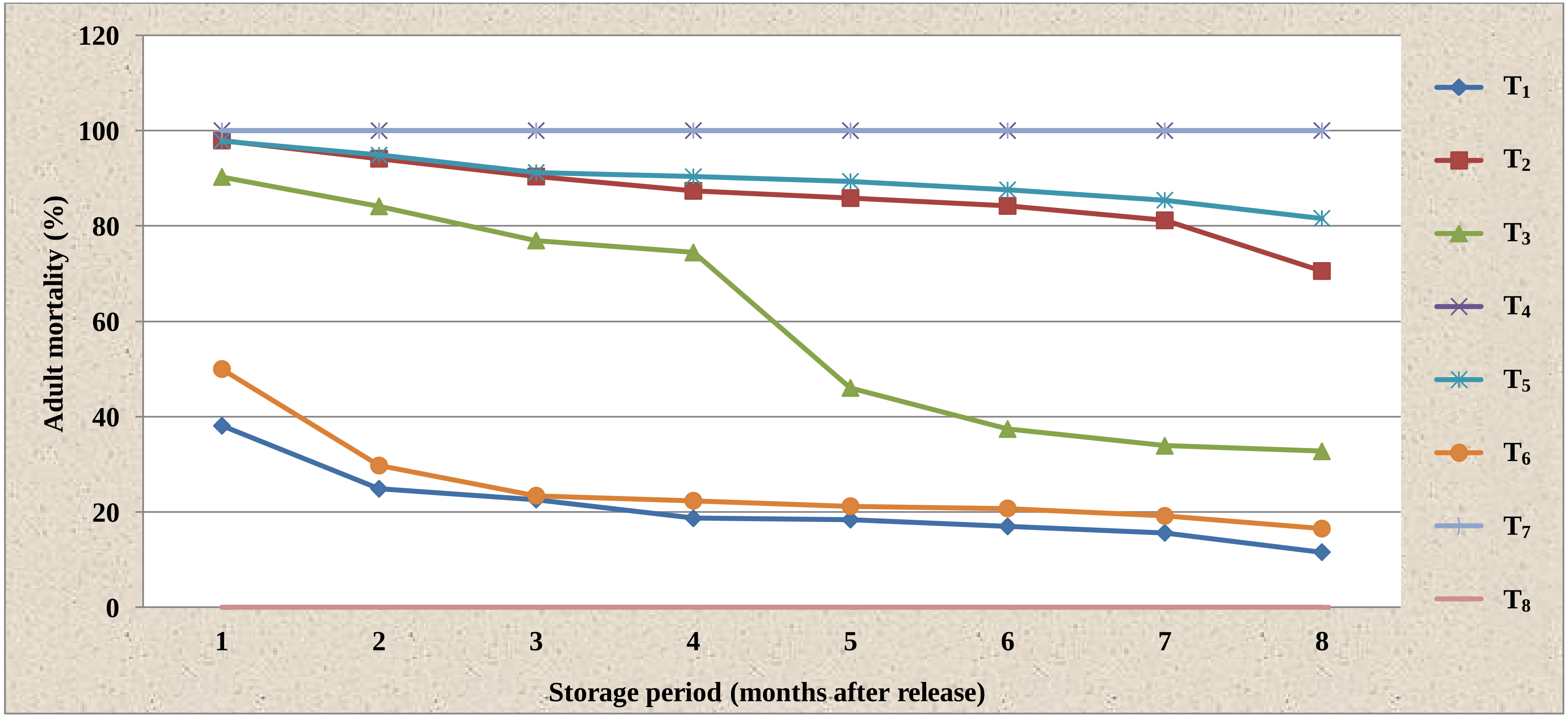


Figure 4.18. Effect of different seed protectant material on adult mortality (%) of pulse bruchid in stored greengram after artificial infestation

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}
T_8 - Untreated control

Plate 4.5. Coconut oil 5ml/ kg treated seed after eight months of infestation

Plate 4.6. Malathion 1g/ kg treated seed (recommended insecticide) after eight months of infestation

Plate 4.7. Untreated control seed after eight months of infestation

During the first month, the adult mortality varied from 0.00 to 100 % among the different treatments. Complete adult mortality (100 %) was noticed in seed treatment with coconut oil and malathion, while adult mortality (0.00 %) was nil in untreated control seed. Same trend was observed during the subsequent months of storage with significant differences among the treatments.

At eight months after storage, the adult mortality ranged from 100 % (coconut oil and malathion dust) to 0.00 % (untreated control) among various treatments with significant differences. Turmeric powder and fly ash registered the less adult mortality (11.59 % and 16.53 %, respectively) among the different seed protectants evaluated, but were superior to untreated control (0.00 %).

Results indicated that among different treatments, coconut oil and malathion dust offered protection against pulse beetle for the longest duration. Bajya *et al*. (2007) also studied the efficacy of some vegetable oils against *C. chinensis* on cowpea seed and reported that neem oil was the most effective with high adult mortality.

4.3.1.4 Seed Weight Loss (%): All the ecofriendly material used as seed protectants were found as significantly superior to untreated control in reducing the weight loss of infested seed throughout the storage period. Irrespective of the seed protectants used, the average seed weight loss increased progressively throughout the storage period from first month (0.72 %) to eighth month (27.37 %) (Table 4.18 and Fig. 4.19).

During the first month, the seed weight loss varied from 0.00 to 0.62 % among the different treatments. The weight loss was not noticed in the coconut oil and malathion dust treated seed, while the weight loss was significantly high in untreated control (0.62 %) seed. Similar trend was observed during the subsequent months of storage with significant differences among the treatments.

After eight months of storage, weight loss in seed was nil in malathion dust and coconut oil treated seed. Turmeric powder and fly ash seed treatments registered the highest seed weight loss (39.40 % and 41.55, respectively) among the different seed protectants evaluated, but were superior to untreated control (74.79 %).

The pooled data on weight loss indicated that the treatments such as turmeric powder (18.92 %) and fly ash (18.44 %) recorded higher seed weight loss but were significantly superior to untreated control (29.34 %). The seed weight loss was nil from coconut oil and malathion dust treated seed.

Table 4.18 Effect of different seed protectant material on seed weight loss (%) of greengram seed artificially infested by pulse bruchidduringthe storage

Treatments	Weight loss (%)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	0.46 (3.89)^{c}	5.80 (13.90)^{a}	9.59 (18.03)^{a}	15.77 (23.29)^{b}	21.50 (26.74)^{ab}	26.97 (31.27)^{b}	31.35 (31.78)^{b}	39.40 (38.86)^{b}	18.92 (25.77)^{b}
Neem leaf powder @ 25 g kg^{-1}	0.33 (3.27)^{d}	1.09 (5.98)^{cd}	1.24 (6.39)^{cd}	2.43 (8.96)^{c}	5.75 (12.72)^{d}	8.61 (17.05)^{c}	12.45 (17.37)	15.51 (23.19)^{c}	5.84 (13.98)^{d}
Neem seed kernel powder @ 5 g kg^{-1}	0.43 (3.76)^{c}	1.39 (6.75)^{c}	1.53 (7.08)^{c}	2.89 (9.72)^{c}	17.27 (20.97)^{c}	20.99 (27.25)^{b}	32.11 (27.76)^{b}	37.96 (38.01)^{b}	14.14 (22.07)^{c}
Coconut oil @ 5ml kg^{-1}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	0.00 (0.00)^{f}
Inert dust @ 5 g kg^{-1}	0.30 (3.15)^{d}	0.87 (5.35)^{d}	1.05 (5.88)^{d}	1.40 (6.80)^{d}	2.98 (9.88)^{d}	5.49 (13.55)^{c}	7.25 (15.73)^{c}	9.77 (18.21)^{d}	3.65 (11.02)^{e}
Fly ash @ 10 g kg^{-1}	0.60 (4.43)^{b}	4.64 (12.42)^{b}	8.18 (16.60)^{b}	15.24 (22.96)^{b}	18.61 (25.54)^{bc}	24.01 (29.33)^{b}	31.68 (34.22)^{b}	41.55 (40.12)^{b}	18.44 (25.42)^{b}
Malathion dust @ 1 g kg^{-1}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{e}	0.00 (0.00)^{d}	0.00 (0.00)^{d}	0.00 (0.00)^{e}	0.00 (0.00)^{f}
Untreated control	0.62 (4.51)^{a}	5.97 (14.13)^{a}	9.46 (17.90)^{a}	18.74 (25.64)^{a}	27.68 (31.73)^{a}	40.67 (39.60)^{a}	56.71 (48.89)^{a}	74.79 (60.00)^{a}	29.34 (32.78)^{a}
Mean	0.72 (3.69)	2.47 (7.32)	3.88 (8.98)	7.06 (12.18)	11.73 (16.65)	15.84 (19.76)	21.44 (23.36)	27.37 (27.30)	11.29 (16.38)
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.14	0.27	0.25	0.39	0.40	0.48	0.51	1.57	**0.27**
C.D. (5%)	0.41	0.81	0.75	1.17	1.21	1.43	1.54	3.34	**0.80**
C.V. (%)	6.41	6.39	4.81	5.57	4.20	4.18	3.81	7.07	**2.83**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different

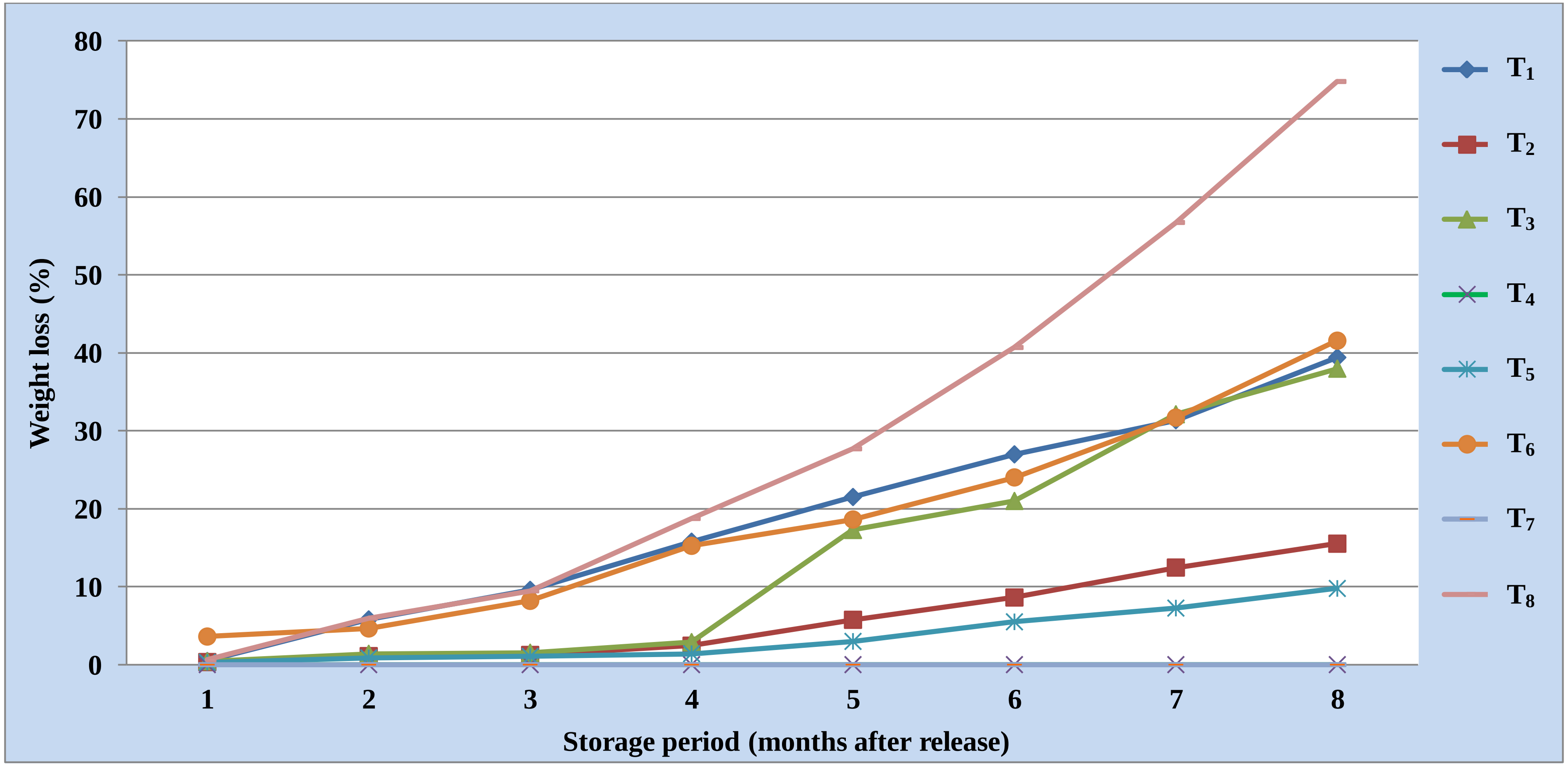


Figure 4.19. Effect of different seed protectant material on weight loss (%) of greengram seed artificially infested by pulse bruchid during the storage

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}
T_8 - Untreated control

The data clearly indicated that the seed treatment with ecofriendly material significantly reduced the weight loss by reducing the egg laying and adult emergence upto eight months of storage. The present results are in harmony with the findings of Govindan and Nelson (2009) and Gill and Singh (2012) who reported that the seed weight loss was low in seed treated with different botanicals as compared to untreated control due to low egg laying and seed infestation by bruchids. Singh *et al.* (2001) recorded highest seed weight loss (47.40 %) in untreated pea grains which considerably reduced to a level of 0.63, 1.00 and 1.10 % by mixing seed with neem oil, neem leaf powder and castor oil, respectively. Sreekanth *et al.* (2011b) opined that coconut oil @ 1.5 ml/ 100 g recorded no weight loss by bruchids up to 180 days after treatment in rajma beans.

4.3.2 Influence of Different Seed Protectant Material on Seed Quality Parameters

The data recorded at monthly interval upto eight months of storage on various seed quality parameters *i.e.,*germination, seedling length, seedling vigour index, electrical conductivity of seed leachates and moisture content of seed were statistically analysed and the results are discussed here under:

4.3.2.1 Germination (%): The initial germination of the seed of LGG-460 variety before seed treatment was 99.00 %. Irrespective of the seed protectants used for seed treatment, the germination declined over the period of storage (Table 4.19). The mean germination declined from 97.42 % after one month to 70.04 % after eight months of storage. Germination in all the seed protectant treatments were found to be significantly superior to untreated control during storage. Significant differences in germination were observed from first to eight months of storage among the different treatments (Table 4.19).

During the first month, the germination varied from 98.67 to 96.33 % among the different treatments. The germination was significantly high in the malathion treated seed (98.67 %) followed by seed treatment with coconut oil (98.33 %), while the germination was significantly low in untreated control seed (96.33 %). Similar trendwas observed during the subsequent months of storage with significant differences among the treatments.

Table 4.19 Effect of different seed protectant material on the germination (%) of greengram seed artificially infested by pulse bruchidduring the storage

Treatments	Germination (%)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	97.00 (79.99)^{b}	94.33 (76.21)^{cd}	87.33 (69.21)^{de}	82.67 (65.41)^{e}	71.33 (57.61)^{d}	61.67 (51.73)^{e}	51.00 (45.55)^{f}	41.67 (40.19)^{d}	**73.38 (58.92)^{c}**
Neem leaf powder @ 25 g kg^{-1}	97.67 (81.22)^{ab}	97.33 (80.61)^{ab}	97.00 (79.99)^{ab}	96.33 (78.95)^{b}	95.00 (77.05)^{b}	94.00 (75.79)^{b}	91.33 (72.86)^{c}	93.67 (75.40)^{b}	**95.29 (77.44)^{a}**
Neem seed kernel powder @ 5 g kg^{-1}	96.33 (78.95)^{b}	96.33 (78.95)^{bc}	94.33 (76.44)^{bc}	91.67 (73.23)^{c}	81.67 (64.81)^{c}	75.00 (60.04)^{c}	68.67 (56.01)^{d}	61.33 (51.55)^{c}	**83.17 (65.77)^{b}**
Coconut oil @ 5ml kg^{-1}	98.33 (82.63)^{ab}	97.67 (81.22)^{ab}	97.00 (79.99)^{ab}	96.33 (78.95)^{b}	96.00 (78.43)^{ab}	95.67 (77.97)^{b}	95.33 (77.51)^{b}	95.00 (77.05)^{b}	**96.70 (79.06)^{a}**
Inert dust @ 5 g kg^{-1}	98.33 (81.22)^{ab}	96.67 (79.47)^{bc}	96.00 (78.43)^{b}	95.67 (77.97)^{b}	95.67 (77.97)^{ab}	95.00 (77.05)^{b}	94.67 (76.63)^{b}	94.00 (75.79)^{b}	**95.67 (77.96)^{a}**
Fly ash @ 10 g kg^{-1}	97.33 (80.88)^{ab}	95.67 (78.73)^{bcd}	90.67 (72.71)^{cd}	87.33 (69.33)^{d}	77.33 (61.63)^{c}	66.67 (54.72)^{d}	59.67 (50.55)^{e}	46.33 (42.88)^{d}	**77.63 (61.75)^{bc}**
Malathion dust @ 1 g kg^{-1}	98.67 (84.55)^{a}	98.67 (83.43)^{a}	98.67 (83.43)^{a}	98.33 (82.63)^{a}	98.00 (81.84)^{a}	98.00 (81.84)^{a}	98.00 (81.84)^{a}	97.67 (81.22)^{a}	**98.33 (82.38)^{a}**
Untreated control	96.33 (78.95)^{b}	93.33 (75.02)^{d}	85.33 (67.46)^{e}	80.00 (63.43)^{e}	68.67 (55.98)^{d}	53.67 (47.09)^{f}	40.67 (39.60)^{g}	30.67 (33.55)^{e}	**68.58 (55.89)^{d}**
Mean	97.42 (81.05)	96.25 (79.21)	93.29 (75.96)	91.04 (73.74)	85.46 (69.42)	79.96 (65.78)	74.92 (62.57)	70.04 (59.70)	**86.05 (69.89)**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	1.24	1.21	1.46	1.08	1.32	0.86	0.84	0.98	**0.94**
C.D. (5%)	3.71	3.64	4.38	3.24	3.96	2.58	2.51	2.94	**2.83**
C.V. (%)	2.65	2.66	3.33	2.54	3.29	2.27	2.32	2.84	**2.34**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantly different
Initial germination before seed treatment and artificial infestation was 99.00 %.

After eight months of storage, significantly highest germination was recorded in seed treated with malathion dust (97.67 %) and coconut oil (95.00 %). Turmeric powder and fly ash recorded the less germination (41.67 % and 46.33 %, respectively) among the different seed protectants evaluated, but were superior to untreated control (30.67 %).

The pooled data showed that the treatments such as turmeric powder (73.38 %) and fly ash (77.63 %) recorded less germination but significantly superior over the untreated control (68.58 %), while the germination was highest in malathion dust (98.33 %) and cocnut oil (96.70 %) followed by inert dust (95.67 %) and neem leaf powder (95.29 %) treated seed which were found to be on par with each other.

The present finding are in corroboration with the result of Gebreegziabiher *et al.* (2017) who reported that the treatment with botanical oils reduced germination of sorghum seed compared to treatment with malathion 5% dust. The reduction in seed germination could be because of molds development on the treated seed as the oils increased the moisture content of seed.

The per cent increase in germination due to the infestation by pulse bruchid over untreated control was highest in malathion (218.45 %) followed by coconut oil (209.75 %) treated seed at eight months after storage (Fig. 4.20). The germination of both treated and untreated seed decreased progressively over storage period. Such decrease in germination with increase in ageing period is inevitable in cereals (Mandal and Basu, 1986), pea (Kumar *et al.*, 1997), maize, soybean and sunflower seed (Simic *et al.*, 2007) and blackgram (Ramazeame*et al.*, 2012).

The results revealed that the seed protectants significantly enhanced the viability and quality of treated seed. The quality of treated seed was higher than that of untreated seed for most part of the storage period. The present findings are in agreement with that of Rana *et al.* (2014b) who reported that seed germination increased in treated pea seed as compared to the untreated seed.

4.3.2.2 Seedling Length (cm): The initial seedling length of the seed of LGG-460 variety before seed treatment was 37.78 cm. The mean seedling length was observed todecrease with increase in storage period which varied from 33.02 cm (first month) to 22.59 cm (eighth month) (Table 4.20).

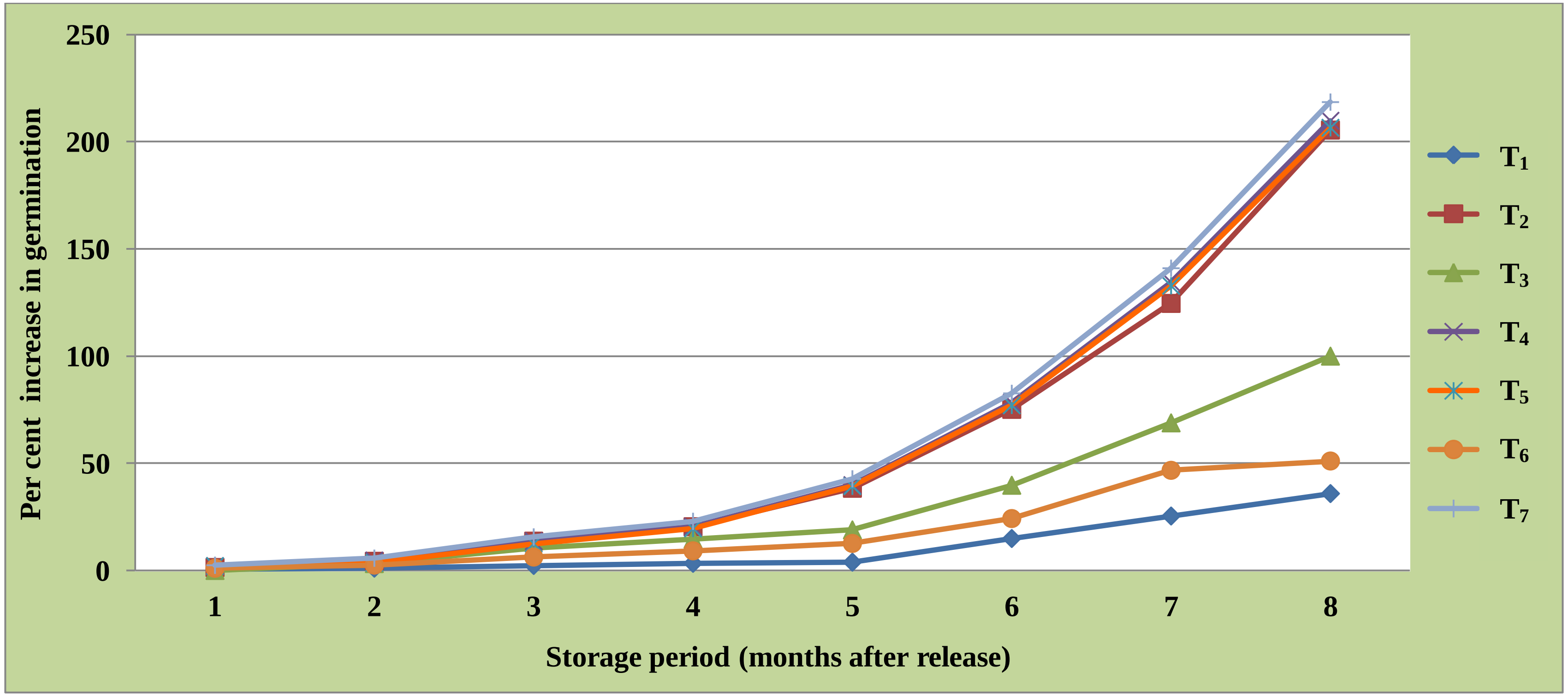


Figure 4.20. Per cent increase in germination due to different seed protectant material in greengram seed artificially infested by pulse bruchid over control during the storage

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}

T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}

T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}

T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}

T_5 - Seed treatment with inert dust @ 5 g kg^{-1}

T_6 - Seed treatment with fly ash @ 10 g kg^{-1}

T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}

During the first month, the seedling length varied from 35.70 to 30.67 cm among the different treatments. The seedling length was significantly high in the seed treated with malathion dust (35.70 cm) followed by coconut oil (34.44 cm), inert dust (34.15 cm) and neem leaf powder (34.05 cm) and were found to be on par with each other, while the seedling length was significantly low in untreated control seed (30.67 cm). Almost similar trend was observed during the subsequent months of storage with significant differences among the treatments.

At the end of storage period *i.e.*, in eighth month, seed treated with malathion dust (32.42 cm), followed by coconut oil (30.70 cm) registered higher seedling length and were found to be on par with each other. Lower seedling length (10.15 cm) was observed in seed treated with untreated control (Table 4.20).

The mean seedling length (pooled) was higher from seed treated with malathion dust (33.84 cm) which was significantly superior to all the treatments. Lower pooled mean seedling length was observed in control (22.14 cm).

The per cent increase in seedling length due to the infestation by pulse bruchid over untreated control was highest in malathion dust (219.41) followed by coconut oil (202.46) at eight months after storage (Fig. 4.21).

Babu and Ravi (2008) also reported that soybean seed treated with botanicals exhibited higher germination, more seedling length and seedling dry weight. Deshpande *et al.* (2010) found that higher seedling length was noticed with sweet flag, malathion dust, neem seed powder and methyl parathion seed treatment due to some insecticidal property leading to higher bruchid mortality with least population build up and lowest seedv weight loss.

4.3.2.3 Seedling Vigour Index: The initial seedling vigour index of the seed of LGG-460 variety before seed treatment was 3740.22. Irrespective of the seed protectant used, seedling vigour index declined progressively over the period of storage (Table 4.21). The mean seedling vigour index declined from 3197 (first month) to 1795 (after eight months of storage).

Table 4.20 Effect of different seed protectant material on seedling length (cm) of greengram seed artificially infested by pulse bruchidduring the storage

Treatments	Seedling length (cm)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	32.58[bc]	30.46[b]	28.05[b]	25.87[bc]	22.74[bc]	20.01[bc]	17.15[c]	13.61[d]	**23.57[d]**
Neem leaf powder @ 25 g kg^{-1}	34.05[ab]	33.51[a]	32.99[a]	32.63[a]	32.05[a]	31.50[a]	30.34[a]	29.22[b]	**32.14[b]**
Neem seed kernel powder @ 5 g kg^{-1}	30.78[d]	29.56[b]	28.99[b]	27.89[b]	24.47[b]	22.20[b]	19.79[b]	17.31[c]	**25.05[c]**
Coconut oil @ 5ml kg^{-1}	34.44[ab]	34.09[a]	33.65[a]	33.40[a]	33.03[a]	32.26[a]	31.50[a]	30.70[ab]	**32.88[b]**
Inert dust @ 5 g kg^{-1}	34.15[ab]	33.55[a]	33.46[a]	33.07[a]	32.21[a]	31.59[a]	30.40[a]	29.43[b]	**32.22[b]**
Fly ash @ 10 g kg^{-1}	31.70[cd]	29.52[b]	28.87[b]	27.03[b]	24.81[b]	22.86[b]	20.52[b]	17.90[c]	**25.40[c]**
Malathion dust @ 1 g kg^{-1}	35.70[a]	34.84[a]	34.48[a]	34.11[a]	33.44[a]	33.19[a]	32.54[a]	32.42[a]	**33.84[a]**
Untreated control	30.67[cd]	29.05[b]	27.21[b]	24.51[c]	21.33[c]	17.78[c]	14.50[d]	10.15[e]	**22.14[e]**
Mean	33.02	31.82	30.96	29.82	28.01	26.42	24.59	22.59	**28.41**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.62	0.52	0.66	0.67	0.84	1.02	0.83	0.80	**0.34**
C.D. (5%)	1.85	1.57	1.98	2.02	2.51	3.07	2.50	2.41	**1.02**
C.V. (%)	3.23	2.85	3.69	3.91	5.18	6.70	5.87	6.17	**2.08**

MAR: Months after release
Means in the same column showing similar alphabets are not significantly different
Initial seedling length before seed treatment and artificial infestation was 37.78 cm.

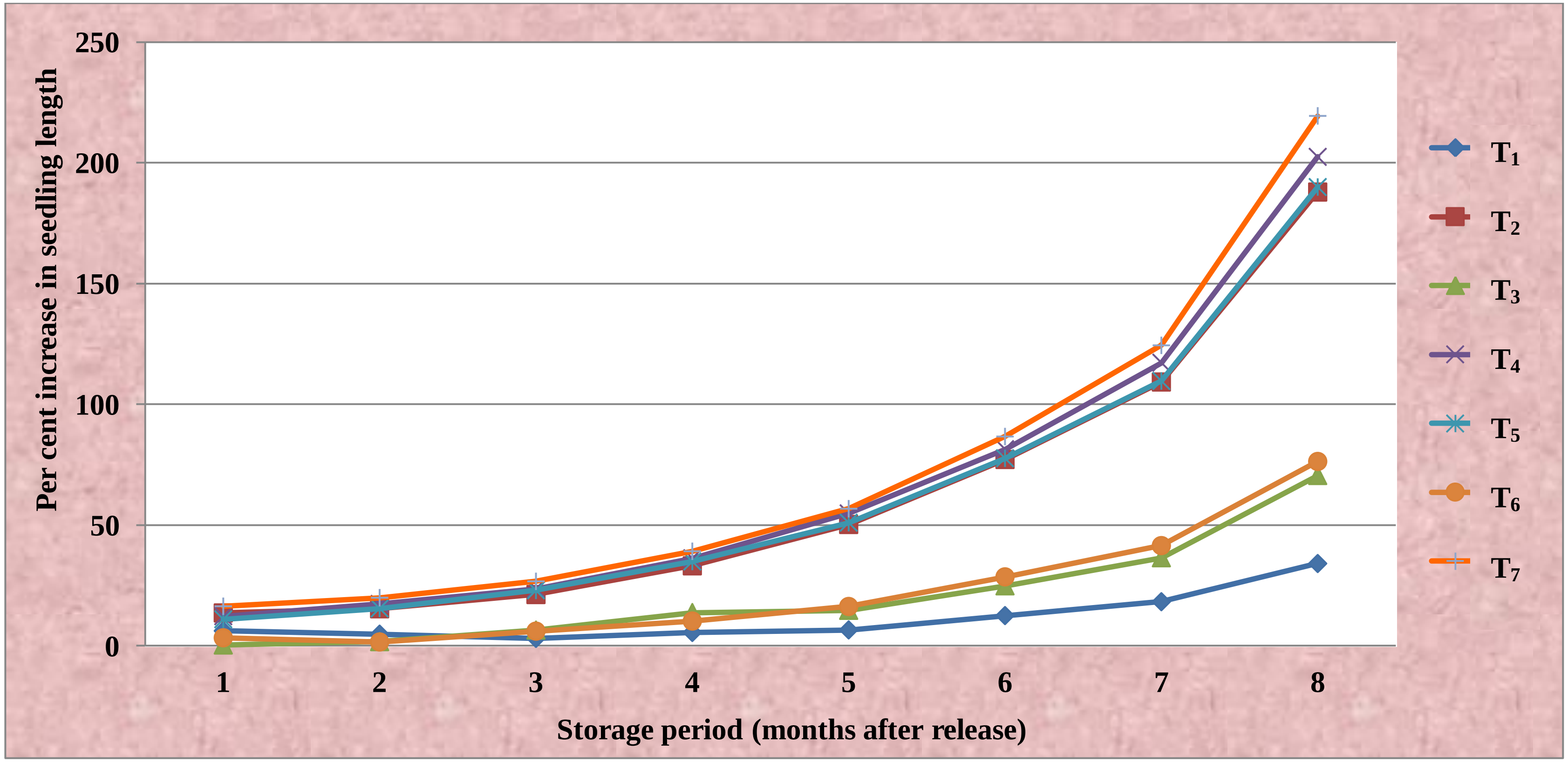


Figure 4.21. Per cent increase in seedling length due to different seed protectant material in greengram seed artificially infested by pulse bruchid over control during the storage

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}

Table 4.21 Effect of different seed protectant material on seedling vigour index of greengram seed artificially infested by pulse bruchidduring the storage

Treatments	Seedling vigour index								
	1 MAR	**2 MAR**	**3 MAR**	**4 MAR**	**5 MAR**	**6 MAR**	**7 MAR**	**8 MAR**	**Pooled**
Turmeric powder @ 20 g kg^{-1}	2975^{ef}	2874^{d}	2450^{e}	2138^{f}	1620^{g}	1234^{f}	875^{g}	567^{g}	**1842de**
Neem leaf powder @ 25 g kg^{-1}	3261^{bc}	3200^{c}	3143^{b}	3111^{c}	3008^{d}	2961^{c}	2767^{d}	2737^{d}	**3024^{b}**
Neem seed kernel powder @ 5 g kg^{-1}	2907^{f}	2847^{d}	2734^{c}	2557^{d}	1998^{e}	1665^{d}	1346^{e}	1062^{e}	**2140^{c}**
Coconut oil @ 5ml kg^{-1}	3387^{ab}	3295^{bc}	3219^{b}	3223^{b}	3166^{b}	3086^{b}	3003^{b}	2917^{b}	**3162^{ab}**
Inert dust @ 5 g kg^{-1}	3364^{ab}	3276^{b}	3208^{b}	3207^{b}	3060^{c}	3001^{c}	2878^{c}	2767^{c}	**3095^{ab}**
Fly ash @ 10 g kg^{-1}	3085de	2824^{d}	2617^{d}	2361^{e}	1906^{f}	1524^{e}	1225^{f}	829^{f}	**2047^{cd}**
Malathion dust @ 1 g kg^{-1}	3457^{a}	3437^{a}	3402^{a}	3354^{a}	3252^{a}	3251^{a}	3189^{a}	3167^{a}	**3314^{a}**
Untreated control	2839^{g}	2711^{e}	2322^{f}	1961^{g}	1468^{h}	954^{g}	590^{h}	311^{h}	**1682^{e}**
Mean	3197	3058	2887	2739	2435	2210	1984	1795	**2538**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	41.68	86.32	69.08	59.32	37.90	44.97	41.01	43.30	**81.54**
C.D. (5%)	124.96	258.80	207.11	177.84	113.62	134.83	122.96	129.82	**244.48**
C.V. (%)	2.26	4.89	4.14	3.75	2.70	3.53	3.58	4.18	**5.56**

MAR: Months after release
Means in the same column showing similar alphabets are not significantly different
Initial seedling vigour index before seed treatment and artificial infestation was 3740.22.

During the first month, the seedling vigour index varied from 3457 to 2839 among the different treatments. The seedling length was significantly high in the seed treated with malathion dust (3457) followed by coconut oil (3387) and inert dust (3364) which were found to be on par with each other, while the seedling vigour index was significantly low in untreated control seed (2839). Seedling vigour index was highest in malathion treated seed and lowest in untreated control seed throughout the storage period with significant differences among the treatments.

At eight months after storage period, highest seedling vigour index recorded in the seed treated with malathion dust (3167) and lower seedling vigour index was observed in seed treated with untreated control (311).

The pooled mean data revealed that the seedling vigour index was higher in seed treated with malathion dust (3314) followed by coconut oil (3162) and inert dust (3095) which were found on par among themselves. The lowest seedling vigour index was observed with turmeric powder (1842) among the different botanical treatments(Table 4.21).

The per cent increase in seedling vigour index due to the infestation by pulse bruchid over untreated control was highest in seed treated with malathion (918) followed by coconut oil (838) at eight months after storage (Fig. 4.22).

Germination and seedling growth were consistently high in treatments with malathion dust as well as coconut oil. Seed vigour is the sum total of all those properties of seed which determine the potential for rapid, uniform emergence and development as normal seedlings under a wide range of field conditions. Increase in seedling length and germination during storage in seed treated with malathion and coconut oil was reflected in higher seed vigour indices. It was observed that all the seed protectant treatments were found significantly superior over untreated control. Similar impact on viability and vigour maintenance by seed treatment with plant oils and botanicals and insect control has been reported earlier in pulses by several workers (Lele and Mustapha, 2000., Songa and Rono, 2010., Raja *et al.,* 2013., Asawalam and Anaeto, 2014 and Wahedi *et al.,* 2015) which are confirming the present results.

4.3.2.4 Electrical Conductivity of Seed Leachates (dSm^{-1}): The initial electrical conductivity of seed leachates of bulk seed LGG-460 variety, which was used for seed treatment with different eco-friendly materials was 0.40 dSm^{-1}. Irrespective of the seed

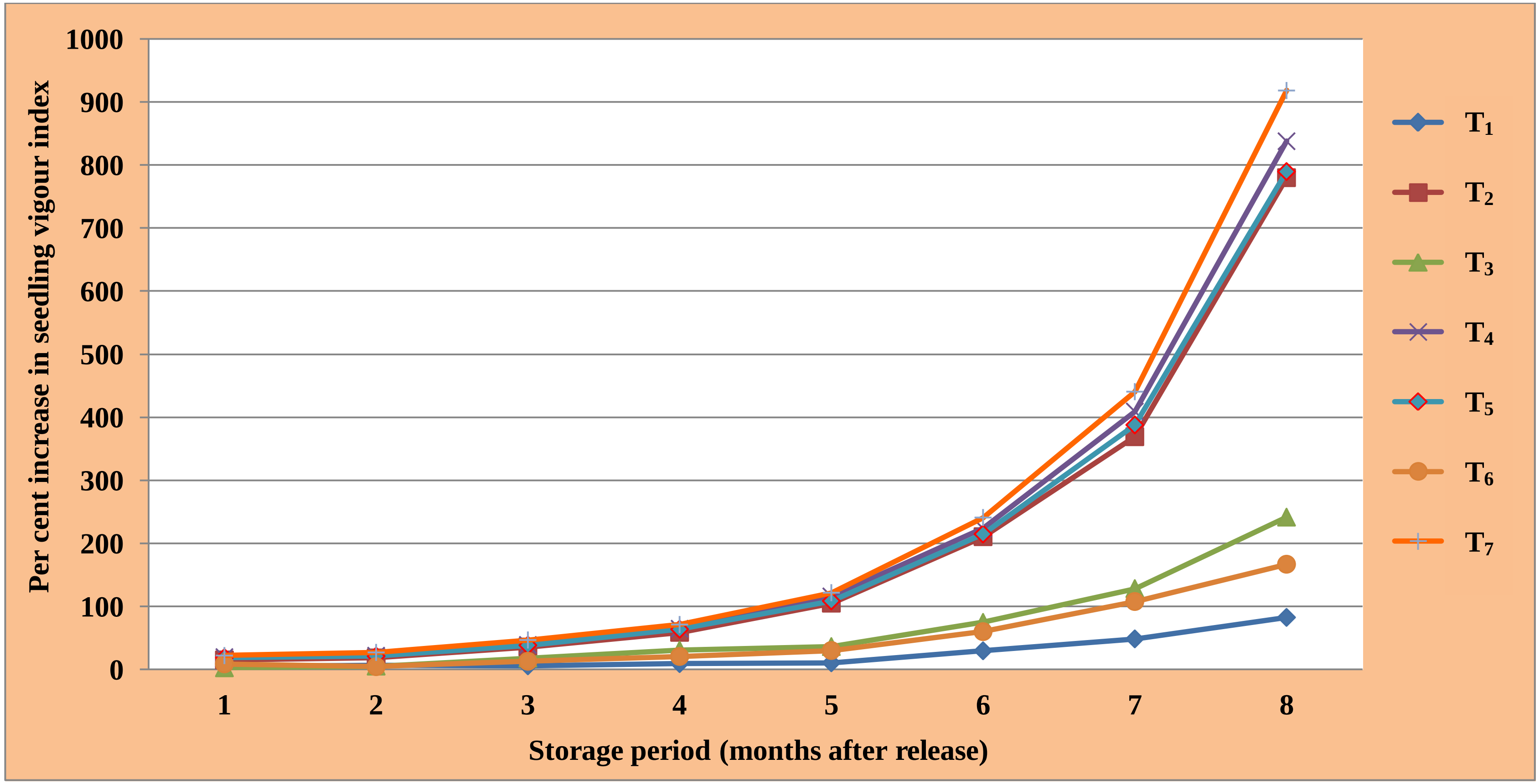


Figure 4.22. Per cent increase in seedling vigour index due to different seed protectant material in greengram seed artificially infested by pulse bruchid over control during the storage

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}

protectants used for seed treatment, the mean electrical conductivity of seed leachate increased progressively over the period of storage varied from 0.43 dSm^{-1} in first month to 1.44 dSm^{-1} in eighth month (Table 4.22 and Fig. 4.23).

During the first month, all the treatments with seed protectant material were statistically on par among themselves for electrical conductivity of seed leachates. Untreated control seed recorded highest electrical conductivity of seed leachates.

After eight months of storage, lower electrical conductivity (0.50 dSm^{-1}) was observed in seed treated with coconut oil and malathion dust (0.50 dSm^{-1}), while highest electrical conductivity of seed leachate was recorded from untreated control (2.67 dSm^{-1}) which was significantly higher when compared to other treatments.

The pooled data showed that untreated control recorded significantly highest electrical conductivity of seed leachates. The treatments with seed protectants such as turmeric powder (1.23 dSm^{-1}) and fly ash (1.14 dSm^{-1}) recorded highest electrical conductivity, while the electrical conductivity was lowest in coconut oil (0.45 dSm^{-1}) followed by malathion dust (0.46 dSm^{-1}) and inert dust (0.47 dSm^{-1}) treated seed which were found to be on par with each other.

The mean electrical conductivity of seed treated with different materials was lower when compared to untreated control seed throughout the storage period. This may be due to the reduced seed membrane permeability in the untreated seed. The nature and extent of membrane protection offered may not be same for all treatments, resulting in differential electrical conductivity values among seed protectant treatments. Botanicals serve as antifeedants and make seed unpalatable to insects, thus reducing the cracks and aberrations of seed coat and minimizing the leaching of the electrolytes.

Saha and Sultana (2008) already noticed increase in electrical conductivity of seed leachate with increase in storage period in soybean.

4.3.2.5 Seed Moisture Content (%): Initially, the moisture content of the seed of LGG-460 was 9.00 % before treatment which was slightly increased by eighth month and there were no significant differences among the treatments for this trait. Pooled mean moisture content over the storage period ranged from 9.01 per cent (malathion dust) (Table 4.23) to 9.51 per cent (untreated control).

Table 4.22 Effect of different seed protectant material on electrical conductivity of seed leachates of greengram seed artificially infested by pulse bruchidduring the storage

Treatments	Electrical conductivity (dSm^{-1})								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	0.43^{b}	0.60^{b}	0.67^{b}	0.97^{b}	1.27^{b}	1.67^{b}	2.03^{b}	2.23^{b}	**1.23^{b}**
Neem leaf powder @ 25 g kg^{-1}	0.40^{b}	0.40^{d}	0.40^{d}	0.40^{e}	0.50^{e}	0.53^{e}	0.70^{e}	0.83^{e}	**0.52^{e}**
Neem seed kernel powder @ 5 g kg^{-1}	0.40^{b}	0.40^{d}	0.40^{d}	0.50^{d}	0.97^{d}	1.47^{d}	1.77^{d}	2.03^{d}	**0.99^{d}**
Coconut oil @ 5ml kg^{-1}	0.40^{b}	0.40^{d}	0.40^{d}	0.40^{e}	0.50^{e}	0.50^{e}	0.50^{f}	0.50^{g}	**0.45^{f}**
Inert dust @ 5 g kg^{-1}	0.40^{b}	0.40^{d}	0.40^{d}	0.40^{e}	0.50^{e}	0.50^{e}	0.53^{f}	0.63^{f}	**0.47^{f}**
Fly ash @ 10 g kg^{-1}	0.43^{b}	0.50^{c}	0.60^{c}	0.83^{c}	1.10^{c}	1.57^{c}	1.93^{c}	2.13^{c}	**1.14^{c}**
Malathion dust @ 1 g kg^{-1}	0.40^{b}	0.40^{d}	0.40^{d}	0.50^{d}	0.50^{e}	0.50^{e}	0.50^{f}	0.50^{g}	**0.46^{f}**
Untreated control	0.53^{a}	0.73^{a}	0.83^{a}	1.07^{a}	1.47^{a}	1.87^{a}	2.27^{a}	2.67^{a}	**1.43^{a}**
Mean	0.43	0.48	0.51	0.63	0.85	1.08	1.28	1.44	**0.84**
F-test	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	Sig.	**Sig.**
SEm ±	0.02	0.01	0.02	0.02	0.02	0.03	0.03	0.03	**0.01**
C.D. (5%)	0.06	0.04	0.05	0.06	0.06	0.08	0.08	0.09	**0.03**
C.V. (%)	8.32	4.26	5.63	5.58	4.16	4.25	3.57	3.47	**2.16**

MAR: Months after release

Means in the same column showing similar alphabets are not significantly different

Initial electrical conductivity of seed leachates before seed treatment and artificial infestation was 0.40 dSm^{-1}.

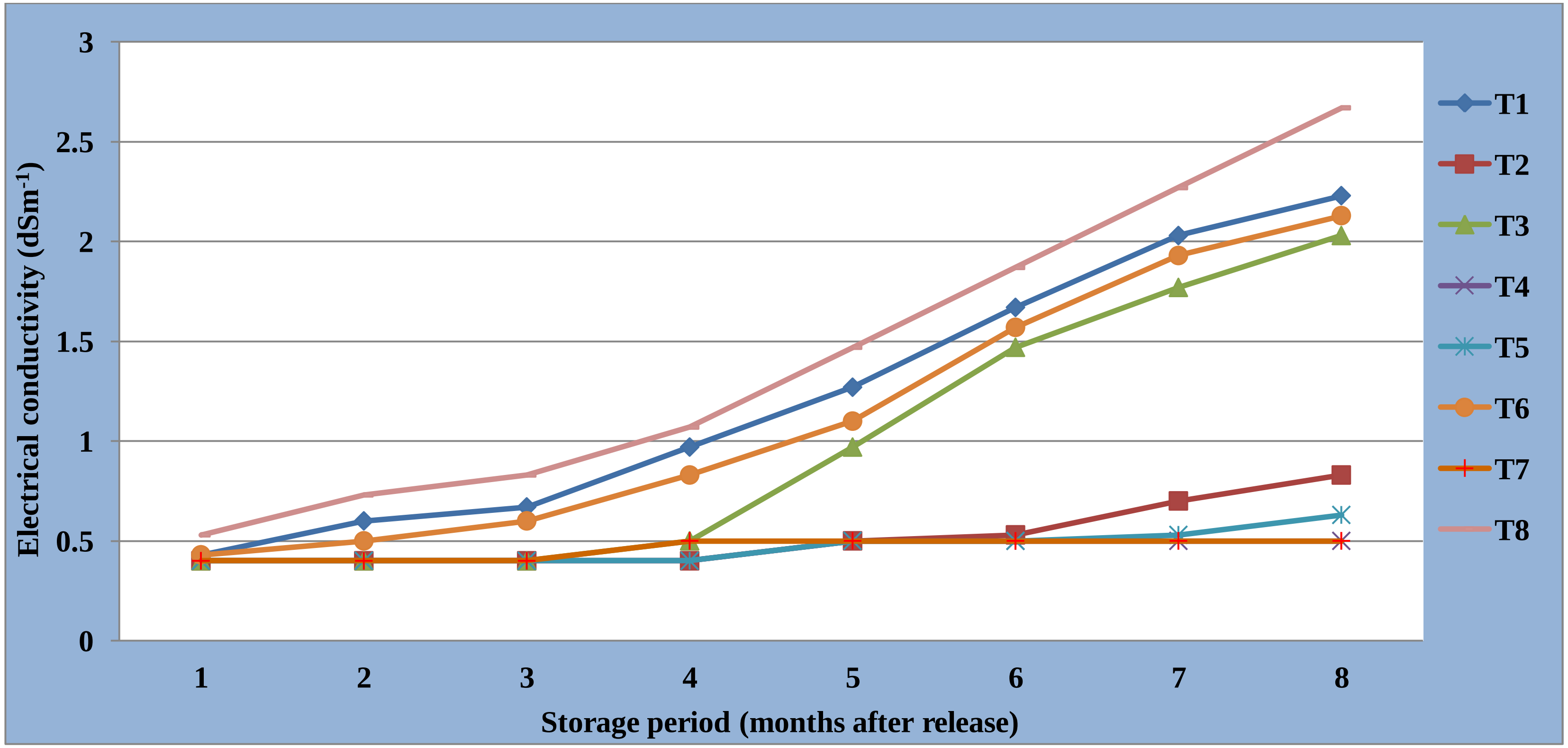


Figure 4.23. Effect of different seed protectant material on electrical conductivity of greengram seed artificially infested by pulse bruchid during the storage

T_1 - Seed treatment with turmeric powder @ 20 g kg^{-1}
T_2 - Seed treatment with neem leaf powder @ 25 g kg^{-1}
T_3 - Seed treatment with neem seed kernel powder @ 5 g kg^{-1}
T_4 - Seed treatment with coconut oil @ 5ml kg^{-1}
T_5 - Seed treatment with inert dust @ 5 g kg^{-1}
T_6 - Seed treatment with fly ash @ 10 g kg^{-1}
T_7 - Seed treatment with malathion dust @ 1 g kg^{-1}
T_8 - Untreated control

Table 4.23 Effect of different seed protectant material on moisture content (%) of greengram seed artificially infested by pulse bruchid during the storage

Treatments	Moisture content (%)								
	1 MAR	2 MAR	3 MAR	4 MAR	5 MAR	6 MAR	7 MAR	8 MAR	Pooled
Turmeric powder @ 20 g kg^{-1}	9.03 (17.48)[b]	9.10 (17.55)[b]	9.23 (17.68)[b]	9.27 (17.72)[ab]	9.30 (17.75)[b]	9.40 (17.85)[b]	9.60 (18.04)[b]	9.83 (18.27)[c]	**9.35 (17.79)[b]**
Neem leaf powder @ 25 g kg^{-1}	9.00 (17.45)[b]	9.00 (17.45)[c]	9.00 (17.45)[d]	9.00 (17.45)[d]	9.07 (17.52)[d]	9.20 (17.65)[d]	9.27 (17.72)[d]	9.33 (17.78)[e]	**9.11 (17.56)[d]**
Neem seed kernel powder @ 5 g kg^{-1}	9.10 (17.55)[a]	9.10 (17.55)[b]	9.10 (17.55)[c]	9.13 (17.58)[c]	9.20 (17.65)[c]	9.33 (17.78)[c]	9.50 (17.94)[c]	9.70 (18.14)[d]	**9.27 (17.72)[c]**
Coconut oil @ 5ml kg^{-1}	9.00 (17.45)[b]	9.00 (17.45)[c]	9.00 (17.45)[d]	9.00 (17.45)[d]	9.00 (17.45)[e]	9.00 (17.45)[e]	9.03 (17.48)[ef]	9.10 (17.55)[g]	**9.02 (17.47)[f]**
Inert dust @ 5 g kg^{-1}	9.00 (17.45)[b]	9.00 (17.45)[c]	9.00 (17.45)[d]	9.00 (17.45)[d]	9.00 (17.45)[e]	9.03 (17.48)[e]	9.10 (17.55)[e]	9.20 (17.65)[f]	**9.04 (17.49)[e]**
Fly ash @ 10 g kg^{-1}	9.10 (17.55)[a]	9.10 (17.55)[b]	9.20 (17.65)[b]	9.23 (17.68)[b]	9.30 (17.75)[b]	9.43 (17.88)[b]	9.63 (18.07)[b]	9.90 (18.33)[b]	**9.36 (17.81)[b]**
Malathion dust @ 1 g kg^{-1}	9.00 (17.45)[b]	9.00 (17.45)[c]	9.00 (17.45)[d]	9.00 (17.45)[d]	9.00 (17.45)[e]	9.00 (17.45)[e]	9.00 (17.45)[f]	9.10 (17.55)[g]	**9.01 (17.46)[f]**
Untreated control	9.10 (17.55)[a]	9.17 (17.62)[a]	9.30 (17.75)[a]	9.33 (17.78)[a]	9.40 (17.85)[a]	9.60 (18.04)[a]	9.93 (18.36)[a]	10.23 (18.65)[a]	**9.51 (17.95)[a]**
Mean	9.04 (17.49)	9.06 (17.51)	9.10 (17.55)	9.12 (17.57)	9.16 (17.61)	9.25 (17.70)	9.38 (17.83)	9.55 (17.99)	**9.21 (17.66)**
F-test	NS	NS	NS	NS	NS	NS	NS	NS	**NS**
SEm ±	0.01	0.01	0.01	0.02	0.01	0.02	0.02	0.02	**0.01**
C.D. (5%)	0.04	0.04	0.03	0.07	0.04	0.06	0.07	0.06	**0.03**
C.V. (%)	0.12	0.12	0.11	0.23	0.12	0.20	0.22	0.19	**0.08**

MAR: Months after release
Figures in parenthesis are arc sine transformed values
Means in the same column showing similar alphabets are not significantlydifferent
Initial moisture content before seed treatment and artificial infestation was 9.00 %.

After eight months of storage period, malathion dust and coconut oil (9.10 %) recorded the lowest moisture content which was significantly less over other treatments and untreated control (10.23 %) (Table 4.23). From the data, it was found that the higher per cent of moisture induces higher infestation of seed. Hence the results clearly indicated that the use of seed protectants significantly reduced the moisture development in stored seed, and there by maintains the quality of seed and reduces the infestation.

Chapter – V

Summary and Conclusions

Chapter V

SUMMARY AND CONCLUSIONS

The present investigation on "Influence of seed physico-chemical properties on bruchid (*Callosobruchus chinensis* L.) and its management in greengram" was carried out under laboratory conditions in Regional AgriculturalResearch Station (RARS), Lam, Guntur andDepartment of Seed Science and Technology, Advanced Post Graduate Centre, Lam, Guntur for a period of eight months from August, 2017 to March, 2018.

Twelve greengram genotypes were collected from the Regional Agricultural Research Station, Lam, Guntur and used for artificial screening under no-choice test for their relative susceptibility or preference by pulse bruchid. The growth parameters were recorded at monthly intervals for eight months. The physical and bio-chemical parameters were used to evaluate the level of bruchid resistance of different greengram genotypes. The breeder seed of greengram variety, LGG-460 was procured from Regional Agricultural Research Station, Lam, Guntur and treated with six botanicals *viz.*, turmeric powder @ 20 g kg^{-1}, neem leaf powder @ 25 g kg^{-1}, neem seed kernel powder @ 5 g kg^{-1}, coconut oil @ 5 ml kg^{-1}, inert dust @ 5 g kg^{-1}, fly ash @ 10 g kg^{-1} and malathion dust @ 1 g kg^{-1} (check as recommended insecticide) along with untreated control to evaluate their efficacy as seed protectants in storage. All the experiments were laid out in Completely Randomized Design with three replications under ambient conditions.

The data on biological parameters of pulse bruchid, seed quality parameters, physical and biochemical properties were collected and statistically analyzed after using proper transformations.

The relative preference of 12 greengram genotypes by pulse bruchid were assessed based on its biological parameters *viz.*, oviposition, adult emergence, mean developmental period, growth index of the test insect and weight loss of seed. The biological parameters of the test insect after artificial infestation was initially low but gradually increased with increase in period of storage. Among the 12 greengram genotypes, PM-5 recorded less number of eggs, low adult emergence, prolonged mean development period, less growth index and lowest seed weight loss. While the entry, WGG-42 was highly preferred for egg laying and development by the insect and recorded high adult emergence, growth index, weight loss and less mean development period.

The 12 greengram genotypes were classified into five categories based on growth index *i.e.*, resistant (0-1.60), moderately resistant (1.60-1.65), moderately susceptible (1.65-1.70), susceptible (1.70-1.75) and highly susceptible (>1.75). Out of 12 greengram genotypes used in the present investigation, five genotypes *viz.*, PM-5 (1.05), LGG-610 (1.06), LGG-607 (1.06), GGG-1 (1.23) and LGG-595 (1.48) were classified as resistant genotypes, while only one genotype, LGG-460 (1.68), was categorized as moderately susceptible and the remaining six genotypes *viz.*, LGG-574 (1.76), TM-92-2 (1.78), LGG-407 (1.95), LGG-450 (2.08), LGG-586 (2.17) and WGG-42 (2.83) were grouped as highly susceptible genotypes

Significant differences were observed in terms of germination, seedling length, seedling vigour index and electrical conductivity among the different greengram genotypes throughout the storage period. Among the 12 greengram genotypes, PM-5 recorded highest germination, seedling length, seedling vigour index, and moisture content, and lowest electrical conductivity. While the genotype, WGG-42 exhibited lowest germination, seedling length, seedling vigour index, and moisture content and highest electrical conductivity. There was a significant decrease in germination and seedling length and increase in electrical conductivity of seed leachates due to the infestation of the *C. chinensis* in all the genotypes with increase in period of storage which canbe attributed to higher weight loss or more damage to the embryo and cotyledons of seed.

All the physical parameters of seed *viz.*, colour, shape, surface texture, seed length and width, seed coat hardness and 100 seed weight were assessed for all the selected greengram genotypes. From the data, it is evident that seeds with light colour shades *i.e.*, olive green or light green colour are not preferred for egg laying by bruchids when compared to green and dark green colour. The varieties with oblong and globose seed shape might be less preferred by the pulse bruchid for egg laying which leads to the less adult emergence and subsequently lower seed damage. The greengram genotypes with smooth surface were much preferred by *C. chinensis* when compared to rough and wrinkled surface for egg laying.

The genotype, PM-5 with more length (4.77 mm), width (3.77 mm) and length width ratio (1.26) recorded less egg count, more development period and less seed weight loss. Seed coat hardness was high in PM-5 (96.00 %) while, it was low in GGG-1 (57.33 %) with significant differences among the genotypes. The data indicated that the genotype, PM-5 with high seed coat hardness recorded less number of eggs, long mean development period and less weight loss and *vice-versa*. Weight of 100 seeds or test weight of greengram genotypes was highest in PM-5 (4.87 g) and the lowest test weight of 3.14 g was observed in LGG-407, LGG-574 and LGG-586. It was observed that test weight had no significant influence on incidence of *C. chinensis*.

Biochemical parameters *viz*., protein content, phenol content and sugar content were estimated for all the genotypes. The genotypes with high protein content were found susceptible and *vice-versa* for insect damage. The protein content was low in PM-5 followed by GGG-1, LGG-607 in fresh seed samples and were found resistant to pulse bruchid. High sugar content was observed in WGG-42 and low sugar content was observed in PM-5, while high phenol content was found in PM-5 and low phenol content was observed in WGG-42 in both fresh seed samples and after eight months of infestation. Hence, it can be conferred that high phenol content had adverse effect, while high content of sugars and proteins favoured the development of pulse bruchid.

The correlation studies showed that biological parameters *i.e.*, number of eggs, adult emergence and growth index had significant positive association with protein content, sugar content, moisture content and electrical conductivity and negative correlation with phenol content, 100 seed weight and seed coat hardness. In contrast, mean development period had negative association with protein content, sugar content, electrical conductivity and moisture content and positive correlation with phenol content, 100 seed weight and seed coat hardness.

Multiple linear regression studies revealed that all the physical and biochemical properties of seed together contributing to a large and significant variation (65 to 87 %) in growth parameters of pulse bruchid. But, none of the properties exerted significant influence individually on bruchid development.

All the seed protectants used were effective against pulse beetle and were significantly superior to control over the period of storage. Among the seed protectants evaluated, highest mortality of adult beetles, lowest number of eggs, lowest adult emergence and lowest seed weight loss were recorded from seed treated with coconut oil which was found on par with malathion dust. Among the different seed protectants, turmeric powder and fly ash registered the lowest mortality of adult beetles, highest number of eggs and adult emergence.

Irrespective of the seed protectants used for seed treatment, the seed quality parameters like germination, seedling length and seedling vigour index decreased progressively, while electrical conductivity and moisture content increased progressively over the period of storage. Germination, seedling length and seedling vigour index in all the seed protectant treatments were found to be significantly superior to untreated seeds during storage. Throughout storage, no significant difference was observed between treatments pertaining to moisture content of seed. Among the seed protectants evaluated, highest germination, seedling vigour index and seedling length and lowest electrical conductivity, moisture content were recorded in seed treated with coconut oil and malathion.

The following conclusions were drawn from the present investigation:

- The genotypes, PM-5, LGG-610, LGG-607, GGG-1 and LBG-595 were found to be resistant against pulse bruchid in storage. Hence, these genotypes can be used in further breeding programme to transfer bruchid resistance.
- Greengram genotypes with smooth texture, oblong or globose shape and light coloured seed might be less preferred by the pulse bruchid for egg laying.
- The greengram genotypes having low sugar content, low protein content and high phenol content were found to be resistant against pulse bruchid.
- Growth parameters of pulse bruchid such as egg laying, adult emergence and growth index had significant positive association with protein content and sugar content and significant negative association with phenol content.
- The mean development period had significant negative association with protein content and sugar content, while significant positive association with phenol content.
- Among the physical parameters, seed coat hardness had no significant influence on any of growth parameters.
- Electrical conductivity and moisture content of seed had significant positive influence on egg laying and adult emergence.

- Among the different botanicals used as seed protectants, coconut oil @ 5 ml kg^{-1} seed was found significantly superior over all the other botanicals and inert material with no adult emergence and no weight loss of seed upto eight months of storage and it was on par with the insecticidal check, malathion dust @ 1 g kg^{-1} seed.

- The other eco-friendly materials which were found effective as seed protectants are inert dust 5 @ g kg^{-1} seed and neem leaf powder 25 @ g kg^{-1} seed.

- The germination, seedling length and seedling vigour index were high in treated seed when compared to untreated control seed. Hence, botanicals and oils can be used as seed protectants for greengram during storage upto eight months without any adverse effect on germination and seedling vigour and can be used as substitutes for insecticidal seed treatment.

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*Original not seen

Note : The pattern of literature cited presented above is in accordance with the guidelines for thesis presentation, Acharya N.G. Ranga Agricultural University, Guntur.

Appendix

Annexure I

MEAN MONTHLY METEOROLOGICAL DATA RECORDED AT REGIONAL AGRICULTURAL RESEARCH STATION, LAM, GUNTUR, ANDHRA PRADESH

Month	Temperature (ºC)			Relativehumidity (%)	Rainfall (mm)	No. of rainy days
	Maximum	Minimum	Mean			
August, 2017	34.1	24.5	**29.3**	79.5	96.7	13
September, 2017	35.1	24.8	29.9	76.7	118.8	09
October, 2017	34.3	22.6	28.5	78.4	106.5	06
November, 2017	33.6	19.8	26.7	73.5	02.5	01
December, 2017	32.0	15.7	23.9	74.0	00.0	00
January, 2018	31.8	15.7	23.8	70.0	00.0	00
February, 2018	34.0	18.7	26.4	63.1	00.0	00
March, 2018	37.2	22.0	29.6	63.9	00.0	00