

## **Botanical pesticides for the management of *Callosobruchus chinensis* infesting chickpea during storage**

### **Abstract:**

The present research on efficacy of botanicals against pulse beetle in stored chickpea was conducted under laboratory conditions at Department of Entomology, SHUATS, Prayagraj, India during 2020-2021. The experiment was carried in the Completely Randomized Design with twelve treatments (Neem oil, Castor oil, Pungam oil and plant powders neem leaf powder, neem seed kernel powder, Vasambu rhizome powder, Turmeric powder, Custard apple leaf powder, Eucalyptus leaf powder, *Lantana camara* leaf powder, Notchi leaf powder, insecticide (Rynaxypyr) and untreated control. The results were evaluated on the basis of adult mortality, weight loss and Feeding Deterrent Index. Vasambu rhizome powder, Neem oil, Castor oil, and Pungam oil were discovered to be the most successful treatments, demonstrating 100% adult mortality, negligible weight loss, and 100% Feeding Deterrent Index. The effectiveness of the plant oils is due to their repellency and ovipositional deterrent effects on stored products and the efficiency of vasambu rhizome powder was due to the presence of active principle, keta osarone which induces premature death of insects.

**Keywords:** *Botanicals, Feeding deterrent index, pulse beetle, mortality, insecticides, weight loss.*

**Abbreviations:** FDI = Feeding deterrent index, HAT=Hours after treatment, DAT= Days after treatment.

### **1. INTRODUCTION :**

Chickpea (*Cicer arietinum* L.) is an venerable crop that has been cultivated in the Middle East, parts of Africa, India and Pakistan for several years. In Southern European nations, West and South Asia it offers high-quality protein and is regarded as the ideal cuisine for the vegetarian population. Chickpea is used in a range of different preparations in cuisine and has a good source of energy i.e. 416 calories/100 gm chickpea along with protein (18-22%), carbohydrate (52-70%), fat (4-10%), minerals (calcium, phosphorus, iron) and vitamins [5]. In India, a total of

98.5 Lha is used for chickpea cultivation, with an average annual production of 119.9 Lt; in Uttar Pradesh, however, only 6.1 Lha and 840 Lt are used. [1]. In addition to production limitations, farmers' storage conditions result in a substantial post-harvest loss of chickpea. The major factor of the heavy loss of the grain legumes in the storage is pulse beetle (*C. chinensis* L.) [28,30]. The pulse beetle, *Callosobruchus chinensis* L. Fab. (Coleoptera: Bruchidae), is a major pest of economically important leguminous grains, such as chick pea, cowpeas, lentils, green gram, and black gram [17]. The larvae consume the pulse grain to the point where it is no longer suitable for human consumption, replanting, or sprouting. Under storage circumstances, they are significant pests of pulse crops in Asia and Africa. [31]. The grain damage was as high as 69.93% under storage condition [25]. Small farmers, village merchants, and typical houses with inadequate storage conditions are particularly affected by this insect.

Serious problems of genetic resistance by insect species, pest resurgence, residual toxicity, photo toxicity, vertebrate toxicity, widespread environmental hazards and increasing costs of application of the presently used synthetic pesticides have directed the need for effective, biodegradable pesticides [11]. This understanding has sparked interest in developing alternative tactics all around the world, including a reconsideration of the use of plant extracts against agriculturally significant insect pests. Materials made of plants, degrade more quickly. Some may function more selectively, be less poisonous to mammals, or delay the emergence of resistance. The primary benefit is that they are easily and reasonably produced by farmers and small-scale industries as unpurified or partially pure extracts. Over the past 20 years, a lot of effort has been made to screen plants in an effort to develop new botanical insecticides that can replace those currently in use. The emergence of adult bruchids is suppressed, the rate of seed damage and oviposition is decreased when leaf, bark, seed powder, or oil extracts of plants are combined with stored grains. [31].

## **2. Materials and methods:**

The experiment was carried invitro at the Department of Entomology, SHUATS, Prayagraj, with ambient room temperature of  $28\pm 2^{\circ}\text{C}$  and relative humidity of 65–70%. The culture of the test insect, pulse beetle was reared on whole chickpea. The plant materials were dried (leaves, rhizomes, and kernels) in the shade before being ground into a fine powder. The plant oils and insecticide (Rynaxypyr) were procured from the local market. The experiment was carried with

13 treatments including control. Plant powders such as Neem seed kernel powder, Neem leaf powder, Vasambu rhizome powder, Turmeric powder, Custard apple leaf powder, Eucalyptus leaf powder, *Lantana camara* leaf powder, Notchi leaf powder @2gm/100gm of seeds) and plant oils such as neem oil, castor oil, Pungam oil @2ml/100gm of seeds and insecticide (Rynaxypyr @ 0.01ml/1kg of seeds) were used and each treatment was replicated thrice.

**2.1.Determination of adult mortality of pulse beetle:**

For the experiment of the pulse beetle's adult mortality, 100g of treated pulses were placed in plastic containers. Before being sealed, fifteen pairs of adults ranging in age from 0 to 24 hours were placed inside each container. The total number of dead beetles was counted at 24, 48, 72, and 96 hours, respectively. It was presumed that the beetle had died when it did not respond to gentle pressure from a fingertip. Dead bruchids were taken out after each counting.

The following formula was used to calculate the adult mortality rate of *C. chinensis*.

$$\text{Mortality (\%)} = \frac{\text{No. of dead beetle}}{\text{Total no. of released beetle}} \times 100$$

[32]

**2.2.Determination of percent weight loss of seed and FDI:**

150g of seeds from different pulses that had been given treatmental concentrations were employed in the trials. Initial seed weights were recorded. 15 pairs of adults aged 0 to 24 were released. The weights of the seeds were once again recorded after 30, 60, and 90 days.

**2.2.1.**Percent weight loss was determined using the following formula:

$$\text{Percent weight loss} = \frac{w-f}{w} \times 100 \quad [15]$$

Where, w = Initial weight of seeds, f = Final weight of seeds.

**2.2.2. Feeding deterrent index:**

Feeding Deterrent Index was calculated by using the formula

$$\text{FDI} = \frac{C - T}{C} \times 100 \quad [14]$$

C = Consumption in control seed (weight loss in control)

T = consumption in treated seed (weight loss in treated)

After the completion of the experiment, the data was statistically analysed using WASP 2.0 statistical software and results were evaluated after proper tabulation of the observations.

**Table. 1. Active ingredients and Insecticidal activity of treatments .**

S.no	Treatments	Active ingredients	Insecticidal activity	Reference
1	Neem Seed Kernel	Tetranortriterpenoids (Azadirachtin, melantriol, salannin, nimbin, nimbidin, etc)	Antifeedent, Repellent, insect growth regulator	<b>Chaudhary et al. (2017)</b>
2	Neem Leaf Powder	Tetranortriterpenoids (Azadirachtin, melantriol, salannin, nimbin, nimbidin, etc)	Antifeedent ,Repellent, Anti inflammatory properties	<b>Stephen and Samuel (2022)</b>
3	Vasambu rhizome powder	keta asarone, Z – asarone	Repellent, Antifeedent	<b>Shinthiya and Razak (2017)</b>
4	Turmeric Powder	Curcumin	Antifeedent, toxicant, Repellent, Growth regulator	<b>Ali et al. (2014)</b>
5	Custard apple leaf powder	Squamocin and squamostatin Alkaloid, isomeric hydroxyl ketones	Repellent and anti ovipositional properties	<b>Khalequzzaman and Sultana (2006)</b>
6	<i>Eucalyptus</i> leaf powder	Globulol, Terpeneol, Limonene, 1,8 cineole, Mono and sesquiterpenes hydro carbons	Repellent, contact toxicity causes mortality	<b>Russo et al. (2015)</b>
7	<i>Lantana camara</i> leaf powder	Lantic acid, Coumaran	Contact toxicity, Antifeedent, Repellent, Suppress progeny production	<b>Rajashekar, et al. (2014)</b>
8	Notchi leaf powder	<u>casticin, isoorientin</u>	Antifeedent, Insect growth regulator	<b>Haridasan et al. (2017)</b>
9	Neem oil	Tetranortriterpenoids (Azadirachtin, melantriol, salannin, nimbin, nimbidin, etc)	Anti fertility agent, Antifeedent, Ovicidal, Larvicidal	<b>Chaudhary et al. (2017)</b>
10	Castor oil	Ricin and Ricinine.	Repellent, Antifeedent, causes suffocation interfering with respiration	<b>Haghtalab et al. (2009)</b>
11	Pongam oil	Karanjin, pungamol, pongapin, glabrin	Oviposition deterrent	<b>Reena et al. (2012)</b>
12	Coragen	Rynaxypyr® active	Act on insect ryanodine receptors. Affected insects rapidly cease eating, become paralysed, and usually die within one to three days.	<b>Juan and Yuejun. (2023)</b>

### 3. RESULTS

**3.1.**The data collected on the effect of different botanicals on the adult mortality of pulse beetle at 24, 48, 72 and 96 hours after application of treatments is presented in the table.2.

Data (Table.1) revealed that the mortality of released adults was highest in treatment, Vasambu rhizome powder @2gm/100 gm of seeds (100.00%) followed by Turmeric powder@2gm/100gm of seeds (98.33%), *Lantana camera* leaf powder @2gm/100gm of seeds (95.00%), Custard apple leaf powder @2gm/100gm of seeds (91.67%), Neem leaf powder @2gm/100gm of seeds (85.00%), *Eucalyptus* leaf powder @2gm/100gm of seeds (83.33%), Notchi leaf powder @2gm/100gm of seeds (81.67%), Insecticide (Rynaxypyr) @0.01ml/1kg of seeds(65.00%) and Neem Seed kernel powder @2gm/100gm of seeds (56.67%).

All the plant oils namely, Neem oil @2ml/100gm of seeds , Castor oil @2ml/100gm of seeds and Pungam oil @2ml/100gm of seeds showed 100% mortality of released adults after 96 hours of treatment.

Neem Seed kernel powder @2gm/100gm of seeds was found to be the least effective treatment, with adult mortality (56.67%) that differed substantially from the untreated control (0.00%).

Treatments (T<sub>3</sub> and T<sub>4</sub>), (T<sub>2</sub> and T<sub>6</sub>), (T<sub>1</sub> and T<sub>12</sub>) and (T<sub>9</sub>, T<sub>10</sub> and T<sub>11</sub>) were found to be at par with each other.

**Table.2. Effect of different botanicals on adult mortality of pulse beetle *C. chinensis* in chick pea at different hours after treatment (HAT).**

S.No.	Treatments	Adult mortality after			
		24Hours	48Hours	72Hours	96Hours
1	Neem Seed kernel powder @2gm/100gm of seeds	6.67 <sup>et</sup>	20.00 <sup>d</sup>	38.33 <sup>f</sup>	56.67 <sup>d</sup>

2	Neem leaf powder @2gm/100gm of seeds	18.33 <sup>cde</sup>	40.00 <sup>c</sup>	66.67 <sup>cd</sup>	85.00 <sup>bc</sup>
3	Vasambu rhizome powder @2gm/100 gm of seeds	96.67 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
4	Turmeric powder@2gm/100gm of seeds	26.67 <sup>bc</sup>	65.00 <sup>b</sup>	75.00 <sup>bc</sup>	98.33 <sup>a</sup>
5	Custard apple leaf powder @2gm/100gm of seeds	31.67 <sup>b</sup>	60.00 <sup>b</sup>	80.00 <sup>b</sup>	91.67 <sup>abc</sup>
6	<i>Eucalyptus</i> leaf powder @2gm/100gm of seeds	11.67 <sup>def</sup>	51.67 <sup>bc</sup>	73.33 <sup>bc</sup>	83.33 <sup>bc</sup>
7	<i>Lantana camera</i> leaf powder@2gm/100gm of seeds	26.67 <sup>bc</sup>	51.67 <sup>bc</sup>	80.00 <sup>b</sup>	95.00 <sup>ab</sup>
8	Notchi leaf powder @2gm/100gm of seeds	20.00 <sup>bcd</sup>	36.67 <sup>c</sup>	58.33 <sup>de</sup>	81.67 <sup>c</sup>
9	Neem oil@2ml/100gm of seeds	98.33 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
10	Castor oil @2ml/100gm of seeds	96.67 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
11	Pungam oil@2ml/100gm of seeds	95.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>	100.00 <sup>a</sup>
12	Insecticide(Rynaxypyr)@0.01ml/1kg of seeds	16.67 <sup>cde</sup>	38.33 <sup>c</sup>	51.67 <sup>e</sup>	65.00 <sup>d</sup>
13	Untreated Control	0.00 <sup>f</sup>	0.00 <sup>e</sup>	0.00 <sup>g</sup>	0.00 <sup>e</sup>
CD at 5%		11.94	15.32	12.89	12.89
SE (m)±		4.11	5.27	4.43	4.43

**3.2.** Data pertaining to effectiveness of botanicals as seed protectants of chickpea on quality parameter of seed weight response against pulse beetle are presented in the table. 3.

### **3.2.1. Weight loss**

The data regarding the weight loss of treated chickpea clearly showed the efficacy of Neem oil @2ml/150gm of seeds, Castor oil @2ml/150gm of seeds, Pungam oil @2ml/150gm of seeds, Insecticide (Rynaxypyr) @0.01ml/1kg of seeds and Vasambu rhizome powder oil @2mg/150gm of seeds which significantly recorded negligible weight loss. Where a weight loss was observed in the seeds treated with Turmeric powder@2gm/150 gm of seeds(7.30%) followed by *Eucalyptus* leaf powder @2gm/150gm of seeds(7.97%), Neem Seed kernel powder @2gm/150 gm of seeds (8.20%), Custard apple leaf powder @2gm/150 gm of seeds (8.63%), Neem leaf powder @2gm/150 gm of seeds (9.97%), *Lantana camera* leaf powder @2gm/150 gm of seeds (9.30%) and Notchi leaf powder @2gm/150 gm of seeds (11.50%) in comparison to maximum weight loss in untreated pulses caused by the infestation of pulse beetle after 90 days of storage.

### 3.2.2.FDI

It has been observed that among all the treatments, Neem oil @2ml/150 gm of seeds, Castor oil @2ml/150gm of seeds, Pungam oil@2ml/150gm of seeds, Insecticide (Rynaxypyr) @0.01ml/1kg of seeds and Vasambu rhizome powder @2gm/150gm of seeds were most effective with highest FDI (100.00%) which differs significantly from all other treatments. This was followed by Turmeric powder @2gm/150gm of seeds(54.16%), *Eucalyptus* leaf powder @2gm/150gm of seeds(50.00%), Neem Seed kernel powder @2gm/150gm of seeds (48.60%), Custard apple leaf powder @2gm/150gm of seeds (45.83%), Neem leaf powder @2gm/150gm of seeds (37.50%), *Lantana camera* leaf powder @2gm/150gm of seeds(41.66%) and Notchi leaf powder @2gm/150gm of seeds (27.76%) which differs significantly from untreated control (0.00%).

**Table.3. Effectiveness of botanicals on percent weight loss of stored chickpea caused by *Callosobruchus chinensis* at 30,60 and 90 days after treatment (DAT).**

S.No.	Treatments	30 DAT	60 DAT	90 DAT
-------	------------	--------	--------	--------

		Weight loss(%)	FDI(%)	Weight loss(%)	FDI(%)	Weight loss(%)	FDI(%)
1	Neem Seed kernel powder @2gm/150gm of seeds	2.87 <sup>cd</sup>	47.22 <sup>bcd</sup>	5.73 <sup>c</sup>	48.15 <sup>c</sup>	8.20 <sup>def</sup>	48.61 <sup>bc</sup>
2	Neem leaf powder @2gm/150gm of seeds	3.30 <sup>bc</sup>	39.35 <sup>cd</sup>	7.97 <sup>b</sup>	28.24 <sup>d</sup>	9.97 <sup>c</sup>	37.50 <sup>e</sup>
3	Vasambu rhizome powder @2gm/150 gm of seeds	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>g</sup>	100.00 <sup>a</sup>
4	Turmeric powder@2gm/150gm of seeds	2.20 <sup>d</sup>	59.72 <sup>b</sup>	4.20 <sup>d</sup>	61.80 <sup>b</sup>	7.30 <sup>f</sup>	54.16 <sup>b</sup>
5	Custard apple leaf powder @2gm/150gm of seeds	3.07 <sup>bcd</sup>	43.98 <sup>bcd</sup>	5.77 <sup>c</sup>	47.92 <sup>c</sup>	8.63 <sup>de</sup>	45.83 <sup>cd</sup>
6	<i>Eucalyptus</i> leaf powder @2gm/150gm of seeds	2.63 <sup>cd</sup>	51.85 <sup>bc</sup>	5.10 <sup>cd</sup>	54.17 <sup>bc</sup>	7.97 <sup>ef</sup>	50.00 <sup>bc</sup>
7	<i>Lantana camera</i> leaf powder@2gm/150gm of seeds	3.30 <sup>bc</sup>	39.35 <sup>cd</sup>	7.73 <sup>b</sup>	27.86 <sup>d</sup>	9.30 <sup>cd</sup>	41.66 <sup>de</sup>
8	Notchi leaf powder @2gm/150gm of seeds	3.77 <sup>b</sup>	31.48 <sup>d</sup>	8.63 <sup>b</sup>	21.53 <sup>d</sup>	11.50 <sup>b</sup>	27.76 <sup>f</sup>
9	Neem oil@2ml/150gm of seeds	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>g</sup>	100.00 <sup>a</sup>
10	Castor oil @2ml/150gm of seeds	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>g</sup>	100.00 <sup>a</sup>
11	Pungam oil@2ml/150gm of seeds	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>g</sup>	100.00 <sup>a</sup>
12	Insecticide(Rynaxypyr)@0.01ml/1kg of seeds	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>e</sup>	100.00 <sup>a</sup>	0.00 <sup>g</sup>	100.00 <sup>a</sup>
13	Untreated Control	5.73 <sup>a</sup>	0.00 <sup>e</sup>	11.07 <sup>a</sup>	0.00 <sup>e</sup>	16.00 <sup>a</sup>	0.00 <sup>g</sup>
CD at 5%		0.86	16.90	1.12	9.08	1.11	6.91
SE (m)±		0.29	5.81	0.38	3.12	0.38	2.38

## **4.DISCUSSION**

**4.1.** Among the different treatments of botanicals used to evaluate the adult mortality of pulse beetle, *C.chinensis*, vasambu rhizome powder and neem oil showed the highest percent adult mortality, this might be as a result of the fact that essential oils from plants are extremely lipophilic and can therefore permeate insect cuticles. [3]. After ten days of treatment, Neem oil was discovered to result in 100% death of *Callasobruchus maculates*, according to [24]. Rhizome powder was found to be lethal, resulting in 100% mortality and completely impeding F1 emergence by ovicidal action, according to [29]. The mortality was noticeably increased in oil-treated seeds compared to controls, according to [33]. Maximum adult mortality of pulse beetle on cowpea seeds treated with neem oil and castor oil was reported by [7].

**4.2.** The beneficial effect of vasambu rhizome powder on maintenance of seed quality was focused to the presence of active principle, keta osarone, which prevent the bruchid infestation and preserved the genetic storage potential of seed [2]. The present data are correlated with the results of [8]. According to [18], chickpea treated with dust from the rhizome of *A. calamus* showed negligible weight loss. The low grain damage and less weight loss in oil treatment might be due to the decrease in number of adult emergence [21]. The results in respect of use of neem oil as seed protectant corroborated with those of [22] who observed no seed damage by *C. chinensis* in seeds of horse gram when treated with neem oil at 5 ml/kg seed. Pigeon pea seeds coated with neem and castor oil gave significant protection against pulse beetle compared to the untreated control [26] also supports the present findings.

## **5.Conclusion**

From the present study, it can be concluded that besides insecticide (Rynaxypyr) all the plant oils neem oil, castor oil and pungam oil and Vasambu rhizome powder were effective in causing the mortality of the pulse beetle and in giving negligible weight loss. They can therefore be used to

successfully shield pulses from this pest while they are in storage. These results suggest that the plant oils and plant powders, which are affordable, environmentally benign can control pest infestation under storage conditions.

## References:

1. **Anonymous. (2020).** Directorate of Economic and Statistics, Ministry of Agriculture & Farmers Welfare (DAC&FW), Govt. of India; 2019-20- IIIrd Adv. Est.
2. **Ananthi M, Sasthri G, Srimathi P, Malarkodi K.** Bio-efficacy of plant products against insect infestation in green gram. *Journal of Entomology and Zoology Studies.* 2017;5(4):733-6.
3. **Abdullahi N, Kabir A, Yushau M.** Studies on the efficacy of lime peel oil in protecting stored maize against adult maize weevils (*Sitophilus zeamais*: Motschulsky). *Journal of Entomology.* 2011;8(4):398-403.
4. **Adusei S, Azupio S. Neem: A Novel Biocide for Pest and Disease Control of Plants.** *Journal of Chemistry.* 2022 Nov 17;2022.
5. **Ali SI, Prasad R.** Rabi pulses: chickpea, lentil, Lathyrus and French bean. *Textbook of Field Crops Production.* New Delhi: Directorate of Information and Publication of Agriculture, Indian Council of Agriculture Research. 2002:317-71.
6. **Ali S, Sagheer M, Hassan M, Abbas M, Hafeez F, Farooq M, Hussain D, Saleem M, Ghaffar A.** Insecticidal activity of turmeric (*Curcuma longa*) and garlic (*Allium sativum*) extracts against red flour beetle, *Tribolium castaneum*: A safe alternative to insecticides in stored commodities. *Journal of Entomology and Zoology Studies.* 2014;2(3):201-5.
7. **Bajya DR, Meena BL, Deshwal HL.** Efficacy of plant products and vegetable oils against pulse beetle, *Callosobruchus chinensis* in cowpea. *Indian Journal of Plant Protection.* 2007;35(1):101-3.
8. **Chander S, Singal SK, Bhanot JP.** Role of grain protectants in integrated pest management of pulse beetle, *Callosobruchus chinensis* (L.) infesting greengram, *Vigna radiata* (L.) Wilczek. *Research on Crops.* 2007;8(2):458.

9. **Chaudhary S, Kanwar RK, Sehgal A, Cahill DM, Barrow CJ, Sehgal R, Kanwar JR.** Progress on *Azadirachta indica* based biopesticides in replacing synthetic toxic pesticides. *Frontiers in plant science*. 2017 May 8;8:610.
10. **Du J, Fu Y.** Diamide insecticides targeting insect ryanodine receptors: Mechanism and application prospect. *Biochemical and Biophysical Research Communications*. 2023 Aug 30;670:19-26.
11. **Elhag EA.** Deterrent effects of some botanical products on oviposition of the cowpea bruchid *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). *International journal of pest management*. 2000 Jan 1;46(2):109-13.
12. **Haghtalab N, Shayesteh N, Aramideh S.** Insecticidal efficacy of castor and hazelnut oils in stored cowpea against *Callosobruchus maculatus* (F.)(Coleoptera: Bruchidae). *Journal of Biological Sciences*. 2009;9(2):175-9.
13. **Haridasan P, Gokuldas M, Ajaykumar AP.** Antifeedant effects of *Vitexnegundo* L. leaf extracts on the stored product pest, *Tribolium castaneum* H.(Coleoptera: Tenebrionidae). *International Journal of Pharmacy and Pharmaceutical Sciences*. 2017;9(3):17-22.
14. **Isman MB, Koul O, Luczynski A, Kaminski J.** Insecticidal and antifeedant bioactivities of neem oils and their relationship to azadirachtin content. *Journal of agricultural and food chemistry*. 1990 Jun;38(6):1406-11.
15. **Kobir MS, Paul S, Harun-Or-Rashid M.** Efficacy of locally available plant seed oils against pulse beetle infesting blackgram. *Journal of Bioscience and Agriculture Research*. 2019;22(01):1823-8.
16. **Khalequzzaman M, Sultana S.** Insecticidal activity of *Annona squamosa* L. seed extracts against the red flour beetle, *Tribolium castaneum* (Herbst). *Journal of Bio-Science*. 2006;14:107-12.
17. **Park C, Kim SI, Ahn YJ.** Insecticidal activity of asarones identified in *Acorus gramineus rhizome* against three coleopteran stored-product insects. *Journal of Stored Products Research*. 2003 Jan 1;39(3):333-42.
18. **Homan R, Yubak D.** Eco-friendly management of pulse beetle. *Journal of Agriculture and Environment*. 2011;12:81-90.

19. **Russo S, Cabrera N, Chludil H, Yaber-Grass M, Leicach S.** Insecticidal activity of young and mature leaves essential oil from *Eucalyptus globulus* Labill. against *Tribolium confusum* Jacquelin du Val (Coleoptera: Tenebrionidae). Chilean journal of agricultural research. 2015 Sep;75(3):375-9.
20. **Rajashekar Y, Raghavendra A, Bakthavatsalam N.** Acetylcholin esterase inhibition by biofumigant (Coumaran) from leaves of *Lantana camara* in stored grain and household insect pests. BioMed Research International. 2014 Jun 15;2014.
21. **Raja M, William SJ.** Impact of volatile oils of plants against the cowpea beetle *Callosobruchus maculatus* (FAB.)(Coleoptera: Bruchidae). International journal of integrative biology. 2008;2(1):62-4.
22. **Ramangoudar H, Vishwantha KP, Subramanya S, Babu CK.** Efficacy of non-chemical seed treatments against pulse beetle (*Callosobruchus chinensis* L.) in horse gram (*Macrotyloma uniflorum* Lam. Verdc.) during storage. Bull. Grain Tech. 2000;33(1):54-8.
23. **Reena SR, Sinha BK.** Evaluation of *Pongamia pinnata* seed extracts as an insecticide against American bollworm *Helicoverpa armigera* (Hubner). International Journal of Agriculture Sciences. 2012;4(6):257-61.
24. **Ram BP, Gopal PS.** Use of botanicals for the management of pulse beetle (*Callosobruchus maculatus*) in lentils. Nepal Agriculture Research Journal. 2000;4:27-30.
25. **Singh, R., Singh, B. and Verma, R. A.** Efficacy of different indigenous plant products as grain protectants against *Callosobruchus chinensis* (Linn) on pea. Indian Journal of Entomology. 2001;63(2):179-181.
26. **Singh PK.** Effect of some oils against pulse beetle, *Callosobruchus chinensis* in infesting pigeon pea. Indian journal of entomology. 2003;65(1):55-8.
27. **Shinthiya SC, Razak TA.** Bio efficacy of certain *Acorus calamus* products against sucking pests of Brinjal. Journal of Entomology and Zoology Studies. 2017;5(5):1574-8.
28. **Southgate BJ.** The importance of the Bruchidae as pests of grain legumes, their distribution and control. The importance of the Bruchidae as pests of grain legumes, their distribution and control.. 1978:219-29.

29. **Shukla R, Kumar A, Prasad CS, Srivastava B, Dubey NK.** Efficacy of *Acorus calamus* L. leaves and rhizome on mortality and reproduction of *Callosobruchus chinensis* L.(Coleoptera: Bruchidae). *Applied Entomology and Zoology*. 2009 May 25;44(2):241-7.
30. **Talekar NS.** Biology, damage, and control of bruchid pests of mungbean. AVRDC; 1988.
31. **Tapondjou LA, Adler CL, Bouda H, Fontem DA.** Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post-harvest grain protectants against six-stored product beetles. *Journal of stored products research*. 2002 Jan 1;38(4):395-402.
32. **Vijayalakshmi G, Elango K, Vasanthi E, Vadivel C, Raj RS, Thennarasi A, Anusha VC.** Insecticidal, oviposition deterrent and antifeedant property of certain plant extracts against pulse beetle, *Callosobruchus chinensis* Linn.(Coleoptera: Bruchidae). *Legume Research-An International Journal*. 2021;44(11):1386-91.
33. **Yadav AS, Bhadauria NS, Jakhmola SS.** Efficacy of edible/non-edible vegetable oils against pulse beetle, *Callosobruchus maculatus* (Fab.) in green gram. *Indian Journal of Entomology*. 2004;66(4):365-6.