Journal of Entomology and Zoology Studies

Available online at www.entomoljournal.com

JEZS Journal of Entomology and Zoology Studies

E-ISSN: 2320-7078
P-ISSN: 2349-6800
JEZS 2017; 5(5): 1526-1533

Received: 11-07-2017
Accepted: 12-08-2017

SJ Prasanthi
Assistant Professor,
Department of Entomology,
Jharkhand Rai University,
Ranchi, Jharkhand, India

Rajesh Kumar
Scientist (Plant protection)
Divyayan KVK, Ranchi,
Jharkhand, India

MK Chakravarty
Sr. Scientist- cum- Associate
Professor, Department of
Entomology, Birsa
Agricultural University,
Ranchi, Jharkhand, India

Correspondence
SJ Prasanthi
Assistant Professor,
Department of Entomology,
Jharkhand Rai University,
Ranchi, Jharkhand, India

Non-chemical methods for the management of pulse beetles: A review

SJ Prasanthi, Rajesh Kumar and MK Chakravarty

Abstract
In tropics, pulse beetles, pose a major threat to stored legumes. Usage of chemical insecticides under storage is not safe for consumption and insects may develop resistance towards those insecticides. So there is an increased need to explore alternative and eco-friendly methods for the management of this pest. The use of plant extracts/oils is gaining importance in the present scenario as they are affordable, safer, and bio-degradable. A little research is done in the area of insect growth regulators against pulse beetles. Though many natural enemies against these bruchids have been reported, their effectiveness under storage conditions is yet to be exploited. Use of host plant resistance is economically sound technique and much lime light could be spread on developing resistant cultivars against major pests under both field and storage conditions. Solar drying/heating, usage of dehumidifiers, bio-thermal seed treatment devices, and hygienic storage structures could largely limit the infestation by pulse beetles. Much research could be done on the application of sterile insect techniques against these pests. In this review, different control measures as mentioned above are discussed in brief with an objective to focus on non-chemical control measures of this pest.

Keywords: Pulse beetles, botanical insecticides, Insect growth regulators, host plant resistance

1. Introduction

Pulse beetles, *Callosobruchus* sp. (Coleoptera: Bruchidae) are cosmopolitan pests and widely distributed throughout the tropical and sub-tropical areas (Giga and Smith, 1983) [35]. Pruthi and Singh (1950) [66] described eight species of *Callosobruchus* L whereas Raina (1970) [68] reduced the possibility of availability of Bruchid to five known species of *Callosobruchus* from India; three are commonly met in stored pulses being i.e. *C. chinensis* L., *C. maculatus* F. and *C. analis* F.

Amongst the stored grain pests of pulses, the pulse beetle, *C. chinensis* L., is considered to be the most important and economic pest (Ahmed *et al*., 2003) [1]. They are found in almost all the pulses in India. In developing, pulse production systems face about 20–25% post-harvest losses as they employ traditional techniques (Maneepun, 2003) [51]. Caswellet (1973) [18] recorded 50 to 60 per cent of insect damage on pulse grains after six months of traditional storage. Sharma (1984) [86] reported that the differential rate of damage infested by *C. chinensis* in different pulses were reported to be 68, 56, 49 and 52 per cent in cowpea, Bengal gram, red gram and green gram, respectively, over a storage period of six months.

Most of the pulse beetles infest the grains from the field and hidden infestation is not detected before storage. Usage of fumigants and dusts are effective for the control of bruchids, but impractical at farm level because the rural storage structures are generally not air tight. If the food grains are stored for consumption, pesticide application may be harmful to vertebrates (Bekele *et. al.*, 1995) [11]. Injudicious use of pesticides not only affect the environment but also disturb the food chain (Rajendran, 2003) [70] leading to biomagnifications. Development of resistance by stored grain pests against certain insecticides is another limiting factor under consideration. A few strains of *Tribolium castaneum* (Sinha and Watters, 1985) [93] and pulse beetle (Singh and Srivastava, 1983) [92] had already developed resistance against malathion. Under such circumstances, non-chemical methods, botanical insecticides, insect growth regulators, host plant resistance, atmospheric regulation, and irradiation technique, can be employed to manage the pest while retaining the grain quality. These include seed coating by plant extracts/oils (Schoonhoven, 1978) [78], seed drying by bio-electrical thermal device (Monica and Natarajan, 2016) [55], integrating host plant resistance (Pedigo, 1996) [64], controlled atmosphere, release of natural enemies (Doumma *et al*., 2010) [27], dielectric heating (radio frequency (RF) and microwave (MW) (Fu, 2004) [33], irradiation techniques leading to male sterility (Faruki *et al*., 2007) [32], usage of pheromone traps and insect growth regulators (IGR) (Ukeh *et al*., 2013) [103] etc. The use of plant oils as grain protectants is affordable as the farmers can make use of locally available raw materials. The present paper reviews the various non-chemical methods for the management of pulse beetles.

2. Grain protection with botanicals

Recent researchers have revealed how bioactive compounds of indigenous plant extracts have various effects on insects i.e., anti-feedant action, insect growth regulatory activity inhibits juvenile hormone synthesis, oviposition deterrent, repellant action, reduction of life span of adults and intermediates are formed giving rise to larval-pupal, nymphal-adults, and pupal-adult intermediates and the mode of action of oils is partially attributed to interference in normal respiration, resulting in suffocation (Schoonhoven, 1978) [78]. However, factors other than oxygen starvation probably also play a role in their mode of action (Shaaya & Ikan, 1978) [79]. Egg mortality has been attributed to toxic components and also to physical properties, which cause changes in surface tension and oxygen tension within the egg. It is also thought that oils exert some lethal action on developing embryos or first- instar larvae, for example, by the reduction in rate of gaseous exchange due to a barrier effect and/or direct toxicity by penetrated oil fractions (Don Pedro, 1989) [26]. According to Lale (1991) [47], the insecticidal activity of the essential oils is by acquiring lethal amounts of essential oil by contact or by topical application. But according to Rani and Osmani (1984) [73], essential oil could not serve as contact poison due to their poor ability to penetrate into insect integument. Active ingredients of various plants are mentioned in the table 1.

Table 1: Active ingredients of plant extracts

Name of the plant	Potential active ingredients	reference
Neem (*Azadirachta indica*)	tetranortriterpenoids (Azadirachtin, melantriol, salannin, nimbin, nimbidin, etc	Reddy, 2010. [74]
Karanj (*Pongammia pinnata)*	Furanoflavonoid (karanjin, pongamol, pongapin, glabrin, karanja chromene, karanjone and pongaglabrone	Bringi, 1987. [16]
Castor (*Ricinus communis*)	ricin and ricinine	*Ramos-López,* 2010. [72]
Sesame (*Sesamum indicum*)	Sesamin and sesamolin	Beroza, 1954. [12]
Clove (*Syzygium aromaticum*)	Eugenol (4 allyl-2-methoxy phenol; $C_{10}H_{12}O_2$), a organic phenol compound	Shapiro, 2012. [85]
Soybean (*Glycine max*)	Emulsifiable concentrate formulations of soybean oil	EPA, 1993. [30]
Mahua (*Madhuca latifolia*)	*saponin*, an alkaloid glucoside (leaves), *Sapogenin* and other basic acid (seeds)	Sunitha and Sarojini, 2013. [99]
Mustard (*Brassica sp*) Horseradish (*Armoracia rusticana*) Wasabi (*Eutrema japonicum*)	Allyl isothiocyanate (AITC)	Olivier *et al*., 1999 [63]; Yu *et al*., 2003 [107].

2.2 Effect of plant extracts on various growth parameters of pulse beetles

Singh (2003) [91] found that edible and non-edible oils used as surface protectants for pigeon pea against *Callosobruchus chinensis* @ 8 ml/kg seeds proved highly effective in protecting the seeds up to 9 months of storage. Maximum reduction in fecundity (89.1%), and emergence of F1 adult (97.9%), increased developmental period (14.4%) (Namdev *et al.*2014) [58] and parental mortality(91.70 %) (Meghwal *et al.* 2007) [53] was found when neem oil had been used as grain protectant. Hossain *et al.* (2014) [37] recorded that the oils of neem, castor, *karanj*, and sesame at 4.0 to 8.0 ml/kg seed showed significant reduction in seed infestation and weight loss of chickpea seeds. It was observed that neem extract treated pulse seeds were germinated into highest number of normal seedlings in comparison with garlic extract and sevin 85 SP treated seeds (Rahman *et al.* 2013) [67]. Oils of mustard (Singh *et al.* 2006) [90], clove (Okunola and Ofuya, 2007) [62], coconut (Swella & Mushobozy 2007) [100], sesame (1), groundnut (Khalequazzaman *et al*. 2007) [43], mahua (Kumari *et al.* 1999) [45], soybean and corn (Cruz & Cardona, 1981) [23] were also proved to reduce the infestation by pulse beetles significantly. When oils of mustard, cedar, olive, neem, karanj, apricot were used as grain protectants, none of the treatments apparently reduced the seed germination indicating that these vegetable oils can be used safely for the control of *C. chinensis* (Bhardwaj and Verma, 2013) [14].

Other than oils, dried powders of clove, red pepper, black pepper (Aslam *et al.* 2002) [82], turmeric powder (Salam *et al.* 2005) [76], leaves of *Piper nigrum* (Rajpakse, 1989) [71], etc have also been reported to prevent the infestation of *C. chinensis* L. in stored pulses. Ethanolic extracts of leaves of worm's wood *(Artemisia roxburghii* L. and *A. annua* L.), mint (*Mentha longifolia* L. and *M. spicata* L.) and marigold (*Tagetus erecta* L.), and seed kernels of dharek (*Melia azedarach* L.) showed increased seed germination even after six months of treatment (Kiran *et al.* 2015) [44].

3. Host plant resistance

One of the most promising ways to reduce dependence on pesticides in agriculture is to plant insect resistant cultivars, which is one of the most effective, feasible, economical and environmentally safe pest management tactics (Pedigo, 1996) [64]. Resistant varieties have been developed in various legumes crops (Table 2.) and the resistant source can be utilized in breeding programmes. Borthakur (1992) [15] reported that foods on which the pulse beetle was bred influence the number of eggs laid, presumably better foods enabled the larvae to yield adults with a greater potential for egg production. The growth was very fast in cowpea and chickpea but slow in garden pea (Srivastava and Bhatia, 1958) [95]. Chavan *et al.* (1997) [21] reported that brown black grey and red colored seeds of cowpea were preferred by *C. chinensis* L than white colored seeds. But according to Shaheen *et al.* (2006) [83] the chickpea cultivars with rough, wrinkled, hard and thick seed coat were more resistant compared to those having smooth, soft and thin seed coat. According to Neog and Singh (2011) [59], seed characters such as size, volume, color, shape and texture of seed coat were not related with the ovipositional preference of bruchids on different host seeds.

Table 2: Resistant cultivar/variety/accession/wild plants against pulse beetles

Crop	Resistant cultivar/variety/accession/wild plant	Reference
Chickpea	Punjab-91 ICC 4969 CM 3142-2/92, CM 88, CM 3142-3/92, CM72, Pb91 Digvijay and Vijay Lawaghar	Shaheen *et al.* (2006) [83] Erle *et al.* (2009) [31] Shafique & Ahmed 2005 [81]. Kamble *et al.* (2016) [42]. Siddiqua *et al.*, (2013) [89]
Pigeonpea	ICPW 130 and ICPW 66 Type-7 and IPCL-151 MANAK, BAHAR and ICPL-151	Jadhav *et al.* (2012) [40] Chandel & Bhadauria, 2015 [19] Chandel & Bhadauria, 2014 [20]
Cowpea	Pusa Komal, IC328859, IC107466, IC106815 Brazilian cowpea cultivars IT 85F-2687, MN 05-841, B-49, MNC 99-508-1, MNC 99-510-8, TVu 1593, Canapuzinho-1-2 and Sanzi Sambili Brazilian cultivars BR 17, Gurgueia & BRS cauame CP-17, IT-38956 ACM 0502, PGCP 3, NBC 13, CP 235 and PGCP 5 189KD-288, IT 89KD-391, IT 90K-82-2 and IT 97K-499-35 TVU 2027 Botswanan cowpea land races landraces (B339, B383, B013-F and B261-B)	Tripathi, 2012 [101]. Castro *et al.*, 2013 [17] Marsaro & Vilarinho, 2011 [52] Shivanna *et al.* (2011) [87] Nalini *et al.* (2012) [57] Maina *et al.*, (2012) [49] Uddin and Adesiyun (2012) [102] Obopile *et al.*, (2011) [61]
Mung bean	Pusa 105 and Pusa Bold COGG 912	Bajiya *et al.*, (2011) [9] Lazar and Panickar (2013) [48]
Black gram	UH 82-5, IC 8219 and SPS 143 *Vigna mungo* var. *silvestris* VBN3 and VBN4	Duraimurugan *et al.* (2014) [28] Soundararajan *et al.* (2013) [94] Malaikozhundan and Thiravia, (2012) [50]
Greengram	Km-2 and VBN2	Malaikozhundan and Thiravia, (2012) [50]
Hyacinth bean	GI 77	Prasad *et al.* (2013) [65].
Lentil	AEL-49/20 AEL-49/20	Sarwar, 2013 [77].

4. Biological control

Biological control has not been widely used against *Callosobruchus* species, although several species of parasitoid (Table 3.) are recorded. The potential of combining parasitoids with resistant cowpea cultivar IT 81D-994 significantly reduced emergence of *C. maculatus* at storage (Doumma *et al*., 2010) [27].

Table 3: List of natural enemies against pulse beetles

Natural enemy	Description	Remarks/Reference
Dinarmus acutus, D. basalis, D. vagabundus. (Pteromalidae: Hymenoptera)	1. It is a solitary parasitoid that attacks larval, pre-pupal and pupal stages of *Callosobruchus* sp. (Islam and Kabir, 1995) [39].	Artificial rearing is a challenge. The type of bag or cover used for the rearing of the parasitoid is also important (Islam and Kabir, 1995) [39].
Pteromalus cerealella, *P. tritici*	1.It was thought to be a monophagous parasitoid of Angoumois moth (Fulton, 1933) [34]**.** Later it was highly successful in killing *Callosobruchus maculates* (F.) as to other storage insects**.**	
Anisopteromalus calandrae.	2. It is an ecto-parasitoid on the larvae and pupae of pulse beetles *C. maculates* (F.) and this parasitoid preferred younger larvae of the pest.	Laboratory assays made an evidence of the preference of *A. calandrae* to parasitise 4th instar larvae of *C. maculates* (Ngamo *et al.*, 2007) [60]
Uscana lariophaga, U. mukherjii (Hymenoptera: Trichogrammatidae)	3. egg parasitoids 4. *U. lariophaga* females were able to find hosts up to 75 cm horizontal distance from the host patch, which was the largest distance tested (Stolk *et al*., 2005) [96].	Co-existence of *U. lariophaga* did not change the ability of *D. basalis* to suppress *C. maculates* (van Huis *et al.* 2002) [104].
Eupelmus orientalis, E. vuilleti	Parasite larvae/pupae (Anonymous, 2014)[5]	
Lariophagus distinguendus	Parasite larva (Anonymous, 2014) [5]	
Heterospilus prospidis	Parasite larva (Anonymous, 2014) [5]	
Cheyletus eruditus	Predator (Anonymous, 2014) [5]	
Entomopathogenic fungus	*1. Beauveria bassiana* Vanmathi *et al.,* 2011[105]; Shaheen *et al.,* 2016 [62] 2. An isolate (CA-2) of *B. brongniartii* (E-9) of *Metarhizium anisopliae* (Rodrigues and Pratissoli,1999) [75]	3. Fossil shield and Silico-Sec showed synergistic interaction with *B. bassiana* and *M. anisopliae* (Batta, 2008) [10]
Entomopathogenic nematodes	1. *Heterorhabditis bacteriophora, Steinernema siamkayai,* and *S. pakistanense* were among those nematodes that showed the highest virulence 2. The last larval stage of the pulse beetle seems to be more susceptible than the adult (Shahina and Salma, 2009) [84].	

5. IGR and pheromones

Overlap of insect growth regulator (cyromazine) concentration, treatment method and rearing temperature was studied on the southern cowpea weevil, *Callosobruchus maculatus* F. (Bruchidae: Coleoptera), under laboratory conditions. A concentration of 5% cyromazine and dipping treatment at 30 °C showed a significant reduction in the reproductive rate. Moreover, increasing the cyromazine concentration led to a decrease in food consumption and an increase of generation's lifespan (Al-Mekhlafi *et al.* 2011) [2].

A multi attractant lure BFL 225 was used to capture stored insects pests. The predominant insects captured include *Sitophilus* spp., *Plodia interpunctella*, *Tribolium castaneum*, *Callosobruchus maculates*, *Alphitobius laevigatus*, and *Rhyzopertha dominica*. The implied that BFL 225 could be utilized as a part of integrated pest management strategies for early detection of potential insect pests migrating into stored grain warehouses in tropical Africa (Ukeh *et al*., 2013) [103].

6. Hermetic storage control

In controlled Atmosphere Packing (CAP), grain is stored in a modified atmosphere, low in oxygen and with a high concentration of carbon dioxide (CO2) and then the bag is sealed. The conditions within the bag thereafter control breeding insects and fungi, hence no need of any fumigation (Sujeetha *et al.*, 2014) [98]. Modified atmosphere (MA) provides other alternative where additional desired gases (N_2 or CO_2) are generated by pressurized cylinders (Sujeetha *et al.*, 2014) [98]. Triple-layer hermetic bag, made of two plastic bags (made of polyethylene) put inside a third bag made of woven polypropylene is used to protect maize against *Prostephanus truncatus* and *Sitophilus zeamais* and is more cost-effective than the jute and polypropylene bags Anankware *et al*. (2013) [4]. No harmful residues remain after the treatment of the commodity with N_2 or CO_2. When different pulses were exposed to various concentrations of CO_2 i.e. 15 and 20 % (Shivaraja *et al.*, 2012) [88], 18% (Cheng *et al.*, 2013) [22], 40 and 50% (Divya *et al.* 2015) [25] in air tight containers against pulse beetles, it not only checked seed infestation, progeny production, weight loss of seed compared to normal atmosphere but also maintained seed quality without any detrimental effect on germination and seedling vigor up to six months of storage. Hermetic storage technology products are now available from small capacity bags to bigger size “Cocoons” or “Bunkers” and thus makes possible for us to use at household as well as at commercial premises for large storage. Hermetic storage “Cocoons” can also be used for CO_2 treatments of organically produced food grains (Anonymous, 2009) [6].

7. Mechanical control and Physical control

Table 4: Various mechanical and physical control measures against stored grain pests

Particular	Description
Barriers	Movement of adult pulse beetles can be prevented by placing a 7-10cm layer of dry sand/ dry activated clay at the top of grain mass (Lal and Verma, 2007) [46].
storage structures	Pusa bin, Pusa kothar, Pusa cubicle, and improved bamboo basket were found effective as the insect damage was less 1% (Lal and Verma, 2007) [46].
Drying of seeds	1. Seeds can be kept under small transparent polyethylene bags. Solar heating can reduce *Callosobruchus* damage in cowpea (Murdock and Shade, 1991) [56]. 2. If grain temperature is increased up to 60°C and maintained for 10-15 minutes, all live stages of pulse beetles present in pulses are killed (Lal and Verma, 2007) [46]. 3. A novel bio-thermal seed treatment device was developed by Department of Entomology and Department of Bio-energy, TNAU, Coimbatore (Monica and Natarajan, 2016) [55].
Inner dusts	4. Inert diatomaceous earth, activated clay (3), Fly ash (Mendki *et al.*, 2001) [54] when mixed with pulse grains lead to the reduction in the infestation by pulse beetles.

Dielectric heating is a recent technology which covers both radio frequency (RF) and microwave (MW) has been investigated for insect control in foods (Fu, 2004) [33]. Radio frequency (RF) treatments are considered to be a potential postharvest technology for disinfesting legumes of internal seed pests such as the cowpea weevil. The frequency used for MW is 2450 MHz or 915 MHz while for RF the frequency is of 13, 27, or 40 MHz (Wang *et al.*, 2001) [106]. A 27.12MHz, 6kW RF unit with a built-in forced hot air system was used to conduct industrial scale-up studies. A treatment protocol was designed to provide 100% cowpea weevil mortality combined RF with forced hot air to heat product to 60°C for 10min, followed by forced ambient air cooling for 20min (Jiao *et al.*, 2012) [41].

8. Irradiation

Exposure of stored grain pests to ionizing ultraviolet light (wavelengths of 10e 400 nm, photon energies of 3e124 eV) would sterilize, prevent emergence, or have detrimental effect (Faruki *et al*., 2007) [32] by damaging their DNA. Three types of ionizing radiation used on foods are gamma rays from radioactive cobalt-60 and cesium-137, high energy electrons, and X-rays (Shadia and Abd El-Aziz, 2011) [80]. These radiations could sterilize the insects even at lower doses. Seeds of green gram infested with pulse beetles when exposed to electron beam doses viz., 170, 340, 510, 680, 850, 1020, 1190 and 1360 Gy at 500 keV and 700 keV., mortality, longevity and development of the F1 progeny of the surviving adult were found adversely affected. Both the sexes were equally vulnerable (Subadas *et al.* 2011) [97]. *C. maculatus* in cowpea seeds were killed within 8 days of irradiated with 0.25 KGy gamma rays (Darfour *et al*., 2012) [24]. Cent per cent mortality of pulse beetles was observed when the cowpea seeds had been irradiated in a co-60 gamma cell with doses 200Gy, 300Gy and 500Gy. Germination tests subsequently carried out showed that gamma irradiation had no effect on seed viability Enu and Enu, 2014 [29]; Bhalla *et al.*2008 [13].

9. Conclusion

The grubs of pulse beetles feed on the legume reducing the weight and nutritional quality of the grains. Post-harvest losses could be reduced by detecting the hidden infestation. Several non-chemical methods have been recommended to manage the pulse beetles. Although fumigation with insecticides is widely practiced to check the infestation but their application has many negative effects both on environment and consumer disturbing the ecosystem. Irradiation technique is not accepted by the organic farming due to the concerns of customers over the disposal of radioactive wastes. Plant oils could be a better way to overcome pulse beetle and their usage at larger scale could be made possible with seed mixing drums. The potential of combining parasitoids with host plant resistance would reduce the infestation with zero residues of chemicals. The previous research on dielectric heating states that complete mortality of stored grain pests can be achieved by dielectric heating and considered as an eco-friendly alternative to chemical control. Much research is required for the application of controlled atmosphere and dielectric heating for making it available at large scale. Further investigations are required to confirm the results of above research and to attain complete eradication of the insects without deteriorating the product quality.

10. Acknowledgement
Authors express their gratitude to Dr. P.K Singh (Principal Scientist-cum-Professor, Department of Entomology, Birsa Agricultural University, Ranchi) who had provided chickpea seed under AICRP for the research of efficacy of plant oils against pulse beetles, Library of Birsa Agricultural University, and Divyayan KVK of Ranchi.

11. References

1. Ahmed KS, Itino T, Ichikawa T. Duration of developmental stages of *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) on azuki bean and the effect neem and sesame oils at different stages of their development. Pakistan Journal of Biological Sciences. 2003; 6:932-935.
2. Al –Mekhlafi FA, Mashaly AMA, Ahmed A, Mageed MA, Wadaan MA, Mallah Nazar. Overlap effects of cyromazine concentration, treatment method and rearing temperature on the Southern cowpea weevil (*Callosobruchus maculatus F*.) reared on cowpea. African Journal of Microbiology Research. 2011; 5(32):5848-5853.
3. Alice J, Srikanth N. Non-destructive method to manage the most dreaded pest *C. maculatus* (Fab.) in Black gram *Vigna mungo* L. Journal of Stored Products and Postharvest Research. 2013; 4(2):30-34.
4. Anankware JP, Obeng-Ofori D, Afreh –Nuamah K, Fatunbi AO, Martin Bonu-Ire. Triple-Layer Hermetic Storage: A Novel Approach Against Prostephanus Truncatus (Horn) Coleoptera: Bostrichidae) and Sitophilus Zeamais (Mot)(Coleoptera: Curculionidae). Entomol Ornithol Herpetol. 2013; 2:113.
5. Anonymous. 2014. Datasheet: *Callosobruchus maculates* (cowpea weevil). www.cabi.org/isc/mobile/datasheet/10987. Accesed date: 6th February 2017.
6. Anonymous. 2009. Protection of stored grains against pests. Retrieved from https://www.cleanindiajournal.com/protection_of_stored_grains_against_pests/ Accessed date: 11th August 2017.
7. Arora GL, Pajni HR. Some observations on the biology and oviposition of *Bruchus analis* F. (Coleoptera: Bruchidae) Research Bulletin of Punjab University of Zoology. 1957; 128:453-470.
8. Aslam M, Khan KA, Bajwa MZH. Potency of some spices against *C. chinensis* Linnaeus. Journal of Biological Science. 2002; 2(7):449-452.
9. Bajiya RS, Bhargava MC, Singh S. Relative susceptibility of some mung bean, Vigna radiata varieties to *Callosobruchus chinensis* (Linnaeus) during storage. Journal of Insect Sciences. 2011; 24:112-116.
10. Batta YA. Control of Main Stored-Grain Insects with New Formulations of Entomopathogenic Fungi in Diatomaceous Earth Dusts. International Journal of Food Engineering. 2008; 4(1):Art. 9
11. Bekele AJ, Oforiand DO, Hassanali A. Products derived from the leaves of *Occimum kilimandscharicum* (Labiata) as post-harvest grain protectants against the infestation of three major stored product insect pests. Bullitin of Entomological Research. 1995; 85:361-367.
12. Beroza M. Pyrethrum synergists in sesame oil. Sesamolin a potent synergist. Journal of American oil chemist’s society. 1954; 31(7):302-805.
13. Bhalla S, Gupta K, Lal B, Kapur ML, Khetarpal RK. Efficacy of various non-chemical methods against pulse beetle, *Callosobruchus maculatus* Fab. ENDURE International Conference Diversifying crop protection, La Grande-Motte, France. 2008; 1-4, 12-15,
14. Bhardwaj A, Verma SC. Effect of vegetable oils on pulse beetle, C*allosobruchus chinensis* L. (Coleoptera: Bruchidae) infestation and germination of pea seeds (*Pisum sativum*). Pest Management in Horticultural Ecosystems. 2013; 19(1):116-118
15. Borthakur A. Studies on host preference of *Callosobruchus analis* (F.) (Bruchidae: Coleoptera) and evaluation of same safer protectants against the pest. Ph.D. Thesis, Assam Agricultural University, Jorhat-13, 1992.
16. Bringi NV. Non-traditional oil seeds and oils in India. New Delhi: Oxford and IBH, 1987.
17. Castro MJP, Baldin ELL, Cruz PL, Zouza CM, Silva PHS. Characterization of cowpea genotype resistance to *Callosobruchus maculates*. Pesquisa Agropecuaria Brasileira. Brasilia. 2013; 48(9):1201-1209.
18. Caswellet GH. The storage of cowpea. Samaru Agriculture Newsletter, Nigeria. 1973; 15:20-73.
19. Chandel BS, Bhadauria DS. Assessment of resistance to the attack of pulse beetle, *Callosobruchus chinensis* (Fabricius) in chickpea genotypes on the basis of various physical parameters during storage. Journal of Entomology and Zoology Studies. 2015; 3(2):160-165.
20. Chandel BS, Bhadauria DS. Impact of bio-chemical parameters on pigeonpea varieties against egg laying, fecundity and viability of pulse beetle, *Callosobruchus chinensis* (Linn.). Journal of Entomology and Zoology Studies. 2014; 3(2):109-117.
21. Chavan PC, Singh Y, Singh SP. Growth and development of *C. chinensis* on cowpea lines. Indian Journal of Entomology. 1997; 59:303-310.
22. Cheng W, Lei J, Ah JE, Wang Y, Lei C, Zhu-Salzman K. CO_2 enhances effect of hypoxia on mortality, development, and gene expression in cowpea bruchid, *Callosobruchus maculatus* F. Journal of Insect Physiology. 2013; 59(11):1160-1168.
23. Cruz C, Cardona E. Control of dry seed weevils with cooking oil. Journal of Agricultural University. Puerto Rico, 1981, 295-298.
24. Darfour B, Ocloo FCK, Wilson DD. Effects of irradiation on the cowpea weevil (*Callosobruchus maculates* F.) and moisture sorption isotherm of cowpea seed (*Vigna unguiculata* L. Walp). Arthropods. 2012; 1(1):24-34.
25. Divya P, Durga KK, Sunil N, Rajasri M, Keshavulu K, Udayababu P. Modified atmosphere storage technique for the management of pulse beetle, *Callosobruchus chinensis* in Horse gram. Legume Research. 2015;

39(3):474-478

26. Don Pedro KN. Mechanisms of action of some vegetable oils against *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) on wheat. Journal of Stored Product Research. 1989; 25:217-223.
27. Doumma A, Abbas IL, Adam T, Alzouma I. Comportement de vingt variétés de niébé (*Vigna unguiculata* (L.) Walp.) vis-à-vis de Bruchidius atrolineatus (Pic.) etCallosobruchus maculatus (F.) (Coleoptera: Bruchidae. Cahiers Agricultures. 2002; 15:187-193.
28. Duraimurugan P, Pratap A, Singh SK, Gupta S. Evaluation of screening methods for bruchid beetle (*Callosobruchus chinensis*) resistance in greengram (*Vigna radiata*) and blackgram (*Vigna mungo*) genotypes and influence of seed physical characteristics on its infestation.Vegetos- An International Journal of Plant Research. 2014; 27(1):60-67.
29. Enu R, Enu P. Sterilization of grains using ionizing radiation: the case in Ghana. European Scientific Journal. 2014; 10(6):117-136.
30. EPA RED. Facts: Flowers and vegetable oils. 1993, 2.
31. Erle F, Ceylan F, Erdemir, Toker C. Preliminary Results on Evaluation of Chickpea, *Cicer arietinum*, Genotypes for Resistance to the Pulse Beetle, *Callosobruchus maculates.* Journal of Insect Sciences. 2009; 9:58.
32. Faruki SI, Das DR, Khan AR, Khatun M. Effects of ultraviolet (254nm) irradiation on egg hatching and adult emergence of the flour beetles, *Tribolium castaneum*, *T. confusum* and the almond moth, *Cadra cautella*. Journal of Insect Science 2007; 7:16.
33. Fu YC. Fundamentals and industrial applications of microwave and radio frequency in food processing," in Food Processing: Principles and Applications, J. S. Smith and Y. H. Hui, Eds., Blackwell, Iowa City, IA, Iowa, USA, 2004.
34. Fulton BB. Notes on *Habrocytes cerealellae,* parasite *of* the Angoumois grain moth. Annals of Entomological Society of America.1933; 26: 536-553.
35. Giga DP, Smith RH. Comparative life history studies of four *Callosobruchus* species infesting cowpeas with special reference to *C. rhodesianus* (Coleoptera: Bruchidae). Journal of stored Products Research. 1983; 19:189-198.
36. Hossain Alamgir Md, Alim Abdul Md, Shahanara Ahmed K, Haque MA. Insecticidal potentials of plant oils against *Callosobruchus chinensis* (Coleoptera: Bruchidae) in stored chickpea. Journal of Entomological Society of Iran. 2014; 34(3):1-10.
37. Hossain MA, Bachchu MA, Ahmed AKS, Haque MA. Effectiveness of indigenous plant powders as grain protectant against *Callosobruchus chinensis* (l.) in stored chickpea (*Cicer arietinum*). Bangladesh Journal of Agricultural Research. 2014; 39(1):93-103.
38. Hossain MA, Alim MA, Ahmed KS, Haque MA. Biocontrol Potential of *Dinarmus basalis* (Pteromalidae: Hymenoptera) Rondani as a Parasitoid of *Callosobruchus chinensis* (L.) in Stored Pulse. African Entomology. 2014; 22(2):285-290.
39. Islam W, Kabir SMH. Biological control potential of *Dinarmus basalis* (Rond.) (Hymenoptera: Pteromalidae), a larval-pupal ectoparasitoid of the pulse beetle, *Callosobruchus Chinensis* (L.). Crop Protection. 1995; 14(6):439- 443.
40. Jadhav DR, Mallikarjuna N, Rao GVR. *Callosbruchus maculatus* Resistance in Some Wild Relatives and Interspecific Derivatives of Pigeonpea. 2012; 40(1):40:44.
41. Jiao S, Johnson JA, Tang J, Wang S. Industrial-scale radio frequency treatments for insect control in lentils. Journal of Stored Products Research, 2012; 48:143-148.
42. Kamble SM, Bagde AS, Patil RR. Oviposition preference of pulse beetle on different Cultivars of chickpea. Journal of Global Biosciences. 2016; 5(6):4197-4201.
43. Khalequazzaman M, Hussain S, Mahdi A, Osman Goni SHM. Efficacy of edible oils in the control of pulse beetle, *C. chinensis* Linn. in stored pigeon pea. University Journal of Zoology, Rajshahi University. 2007; 26:89-92.
44. Kiran R, Sharma KC, Kanwar HS. Some Botanicals as Seed Protectants against Pulse Beetle, *Callosobruchus chinensis* L. on Pea. Pesticide Research Journal. 2015; 26(2):136-143.
45. Kumari K, Sinha MM, Mehto DN, Hammed SF. Effect of some vegetable oils as protectants gainst pulse beetle, *C. chinensis* Linn. Bulletin of Grain Technology. 1990; 28(1):66-69.
46. Lal RR, Verma, Prasson. Post-harvest management of pulses. Indian Institute of Pulse research, Kanpur. 2007, 26.
47. Lale NES. The biological effect of three essential oils on *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae). Journal of African Zoology. 1991; 105:357-362.
48. Lazar L, Panickar B. Varietal resistance of green gram genotypes/varieties to pulse beetle, *Callosobruchus maculates.* Indian Journal of Entomology. 2013; 75(4):348-351.
49. Maina YT, Mbaya AM, Mailafiya DM. Susceptibility of six local and four improved cowpea cultivars to *Callosobruchus maculatus (F.)* (*Coleoptera: Bruchidae*) infestation in North Eastern Nigeria. Journal of Environmental Issues and Agriculture in Developing Countries. 2012; 4(1):31-37.
50. Malaikozhundan B, Raj S, Thiravia. A study on the developmental biology of *Allosobruchus maculatus* (fabricius) in different pulses. Legume Research: An International Journal. 2012; 35(2):159
51. Maneepun S. Traditional processing and utilization of legumes. In: Shanmugasundaram, S. (Ed.), Report of the APO Seminar on Processing and Utilization of Legumes, Japan, 9– 14 October 2000. Asian Productivity Organization, Tokyo, 2003, 53-62.
52. Marsaro Júnior AL, Vilarinho AA. Resistência de cultivares de feijão-caupi ao ataque de *Callosobruchus maculatus* (Coleoptera: Chrysomelidae: Bruchinae) em condições de armazenamento. Revista Acadêmica: Ciências Agrárias e Ambientais. 2011; 9(1):51-55.
53. Meghwal HP, Singh V, Singh YP. Relative efficacy of some vegetable oils as grain protectant against *Callosobruchus chinensis* (Linn.) on moth bean. Indian Journal of Entomology. 2007; 69(1):22-25.
54. Mendki PS, Maheshwari VL, Kothari RM. Fly ash as a post-harvest preservative or five commonly utilized pulses. Crop Protection. 2001; 20:241-245.
55. Monica D, Natarajan N. Bio-thermal seed treatment device– an innovative technology of heat treatment for the management of bruchids, Callosobruchus maculatus Fab on black gram. International Journal of Farm Sciences. 2016; 6(2):169-175.
56. Murdock LL, Shade RE. Eradication of cowpea weevil

(Coleoptera: Bruchidae) in cowpeas by solar heating. American Entomologist. 1991; 37:228-231

57. Nalini R, Kumari RU, Rajavel DS, Murali Baskaran RK. Studies on relative resistance of cowpea genotypes to *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) Both under field and laboratory condition. Inernational Journal of Advanced Biological Sciences. 2012; 2(3):496-499
58. Namdev HP, Singh RS, Anuragi MK, Chandramani. Efficacy of indigenous oils on growth and development of *C. chinensis* infesting black gram. Annals of Plant Protection Sciences. 2014; 22(2):283-286.
59. Neog P, Singh HK. Qualitative deterioration in the seeds in storage due to *C. chinensis* (L.). Indian Journal of Entomology. 2011; 73(4):371-377.
60. Ngamo TSL, Kouninki H, Ladang YD, Ngassoum MB, Mapongmestsem PM, Hance Thierry. Potential of A. calandrae (Hymenoptera: Pteromalidae) as biocontrol agent of *Callosobruchus maculatus* (F.) (Coleopetera: Bruchidae), 2007. https://www.openaire.eu/search/publication?articleId=od_1493::f40d2e5f16ac42723e04768f84e206be. Accesed date: 06.02.2017.
61. Obopile M, Masiapeto K, Gwafila C. Variation in reproductive and developmental parameters of *Callosobruchus maculatus* (F) reared on ten Botswana cowpea landraces. African Journal of Biotechnology. 2011; 10(63):13924-13928.
62. Okunola CO, Ofuya TI. Effect of some plant oils on insect infestation of stored maize and cowpea. African crop science conference proceedings. 2007; 8:1003-1007.
63. Olivier C, Vaughn SF, Mizubuti ESG, Loria R. Variation in allyl isothiocyanate production within *Brassica* species and correlation with fungicidal activity. Journal of Chemical Ecology. 1999; 25:2687-2701.
64. Pedigo L P. Entomology and Pest Management. Prentice-Hall Inc. 1996, 679.
65. Prasad BSR, Babu CSJ, Gowda MB. Screening *Dolichos* bean (*Lablab purpureas* L.) genotypes for resistance to pulse beetle, *Callosobruchus theobromae* in laboratory. Current Biotica. 2013; 7(3):153-160.
66. Pruthi HS, Singh M. Pests of stored grain and their control. Special number. Indian journal. Agricultural Sciences. 1950; 18(4):36-38.
67. Rahman MS, Ashrafuzzaman M, Sikdar SU, Nayem Zobayer, Ahmad M. Potency of botanical extracts on management of pulse beetle (Callosobruchus chinensis L.). International Journal of Biosciences. 2013; 3(3):76-82.
68. Raina AK. *Callosobruchus* spp. infesting stored pulses (grain legumes) in India and comparative study of their biology. Indian Journal of Entomology. 1970; 32(4):303-310.
69. Rajapkse R, Senanayake SGJN, Rathnasekara D. Effect of five botanicals on oviposition, adult emergence and mortality of *Callosobruchus maculates* F. infesting cow pea, *Vigna ungiculata* L. Walp. Journal of Entomological Research. 1998; 22:117-122.
70. Rajendran S. Environment and health aspects of pesticides use in Indian agriculture. In: Martin J. Bunch, V. Madha Suresh and T. Vasantha Kumaran, (Eds), Proceedings of the Third International Conference on Environment and Health, Chennai, India, 15-17 December, 2003. Chennai: Dept. of Geography, University of Madras and Faculty of Environmental studies. York University, 2003, 353-373.
71. Rajpakse RHS. Effect of five botanicals as protectants of green gram against pulse beetles, *C. chinensis.* pp,85-90. In: Proc. Of 2nd Int. syp. on Bruchids and Legumes (ISBL-2), 1989, 6-9.
72. Ramos-López MA, Pérez S, Rodríguez Hernández GC, Guevara Fefer P, Zavala Sánchez MA. Activity of Ricinus communis (Euphorbiaceae) against Spodoptera frugiperda (*Lepidoptera: Noctuidae*). African journal of biotechnology. 2010; 9(9):1359-1365.
73. Rani PU, Osmani Z. Comparative assessment of topical application and fumigation treatment with certain essential oils for toxicity against *Musca domestica* Nebulo. International Pest control. 1984; 26:44-47.
74. Reddy DS. Chapter 17: Botanicals. In: Applied entomology. 2010, 109.
75. Rodrigues C, Pratissoli D. Pathogenicity of *Beauveria brongniartii* (Sacc.) Petch and *Metarhizium anisopliae* (Mots.) Sorok and their effect on the corn weevil and the bean beetle. Anais da Sociedade Entomológica do Brasil. 1999; 19(2):301-306.
76. Salam MA, Taleb MA, Rahman MA. Screening of some plant material for controlling *C. chinensis* of lentil in storage. Journal of Agriculture and Rural Development. 2005; 3:67-72.
77. Sarwar M. Studies on Resistance Discrepancy in Seeds of Local and Exotic Lentil (*Lens culinaris* Medikus) Genotypes against *Callosobruchus analis* L. (Coleoptera: Bruchidae). African Entomology. 2013; 21(2):273-279.
78. Schoonhoven AV. The use of vegetable oils to protect stored beans from bruchid attack. Journal of Economic Entomology. 1978; 71:254-256.
79. Shaaya E, Ikan R. The effectiveness of vegetable oils in the control of *C. maculutus*. Institute for Technology and Storage of Agricultural Products, Department of Scientific Publications, Special Publication 216, Bet-Dagan, Israel, 1978, 39.
80. Shadia E, Abd El-Aziz SE. Control strategies of stored product pests. Journal of Entomology. 2011; 8(2):101-122.
81. Shafique M, Ahmad M. Chickpea Grains Resistance to Pulse Beetle, *Callosobruchus analis* (F.) (Coleoptera: Bruchidae). Pakistan Journal Zoology. 2005; 37(2):123-126.
82. Shaheen FA, Akram MW, Rashid MA, Nadeem M, Saeed M, Husain M *et al*. Biological control of pulse beetle *C. chinensis* L. (Bruchidae: Coleoptera) in stored chickpea grains using entomopathogenic fungus *B. bassiana* Balsamo. Journal of Entomology and Zoology Studies. 2016; 4(4):1076-1083.
83. Shaheen FA, Khaliq A, Aslam. Resistance of chickpea (*Cicer arietinum* L.) Cultivars against pulse beetle. Paistan Journal of Botany. 2006; 38(4):1237-1244.
84. Shahina F, Salma J. Laboratory evaluation of seven Pakistani strains of entomopathogenic nematodes against a stored grain insect pest, Pulse beetle *C. chinensis* (L.). Pub Med, 2009. https://www.science.gov/topicpages/p/pulse+beetle+callosobruchus.html. Accesed date: 06.02.2017.
85. Shapiro R. Prevention of vector transmitted diseases with clove oil insect repellent. Journal of pediatric nursing. 2012; 27(4):346-349.
86. Sharma. Review of literature on the losses caused by *Callosobruchus* species (Bruchidae; Coleoptera) during storage of pulses. Bulletin of Grain Technology. 1984;

2(1):62- 71.
87. Shivanna BK, Ramamurthy BN, Gangadhara Naik B, Gayathri Devi S, Mallikarjunaiah H, Krishna Naik R. Varietal screening of cowpea against pulse beetles, *C. maculatus* (fab.) And c. Analis (fab.). International Journal of Science and Nature. 2011; 2(2):245-247.
88. Shivaraja DB, Naganagoud A, Sreenivas AG, Kumar U, gouda N, Sushilanada, *et al*. Studies on the effect of O_2 and CO_2 gases at different concentrations on the development of pulsebeetle [*C. analis* (Fabricius)] in pigeonpea. Karnataka Jounal of Agricultural Sciences. 2012; 25(4):427-430.
89. Siddiqua A, Perveen F, Falak Naz, Muhammad Ashfaque. Evaluation of resistance in local chickpea varieties against the pulse beetle, *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). Pakistan Entomologist. 2013; 35(1):43-46, ref.14.
90. Singh KM, Sureja AK, Samra AK. Bio efficacy of some botanicals against *Callosobruchus chinensis* L. (Coleoptera: Bruchidae) on pea. Indian Journal of Entomology. 2006; 68(4):404-406.
91. Singh PK. Effect of some oils against pulse beetle, *Callosobruchus chinensis* (Linn.) infesting pigeon pea. Indian Journal of Entomology. 2003; 65(1):55-58.
92. Singh RP, Srivastava BG. Alcohol extracts of neem (*Azadirachta indica*) seed oil as oviposition deterrent for Dacus cucurbitae. Indian Journal of Entomology. 1983; 45:497-498.
93. Sinha RN, Watters FL. Insect Pests of Flour Mills, Grain Elevators, and Feed Mills and Their Control, Agriculture Canada, Winnipeg, Canada, 1984.
94. Soundararajan RP, Geetha S, Chitra N, Dinakaran D. Resistance in *Vigna mungo* var *silvestris* against Bruchids, *Callosobruchus maculatus* (F.). Annals of Plant Protection Sciences. 2013; 21(2):279-282.
95. Srivastava BK, Bhatia SK. Development of *Callosobruchus chinensis* L. in vegetable seeds. Madras Agriculture Journal. 1958; 45(10):392-395.
96. Stolk C, Ghimire MN, Souquie S, van der Werf and van Huis A. Host finding by *Uscana lariophaga* (Hymenoptera: Trichommatidae) in stored cowpea: the effect of distance, time interval, host patch size and spatial orientation. Bullitin of entomological research. 2005; 95(3):231-241.
97. Subadas S, Shashi B, Bapna SC, Pramod R, Kumar N, Thakur M. Efficacy of Electron Beam Irradiation Against Pulse Beetle, *Callosobruchus Maculatus* (F.) (Coleoptera: Bruchidae). Indian Journal of Entomology, 2011; 73(2):129-132.
98. Sujeetha J, Alice RP, Kavitha Abirami CV, Alagusundaram K. Biointensive safe storage methods for pulses: Review. Journal of Biopesticides. 2014; 7(1):98-103.
99. Sunitha M, Sarojini P. *Madhuca Lonigfolia* (Sapotaceae): A Review of its traditional Uses and Nutritional Properties. International Journal of Humanities and Social Science Invention. 2013; 2(5):30-36.
100. Swella GB, Mushobozy DMK. Evaluation of the Efficacy of protectants against Cowpea Bruchids *Callosobruchus maculatus* (F.) on cowpea seeds *Vigna unguiculata* (L.) Walp.) Plant protectection Sciences. 2007; 43:68-72.
101. Tripathi K. Differential reaction of cowpea genotypes to pulse beetle under artificial seed infestation and biochemical basis of resistance. M.Sc thesis. Published by IARI, Division Of Plant Genetic Resources, 2012.
102. Uddin II RO, Adesiyun AA. Laboratory Investigation on Oviposition and Development of *Callosobruchus maculatus* (F.) on Four Varieties of Cowpea. Agrosearch. 2012; 12(1):31-36.
103. Ukeh DA, Sambo MJ, Isah MD. Response of Potential Stored Grain Insect Pests to BFL 225 Multi-Attractant Lure in Commercial Warehouses. Journal of Biology, Agriculture and Healthcare. 2013; 3(8):87-91.
104. van Huis A, van Alebeek FAN, van Es M, Sagnia SB. Impact of the egg parasitoid *Uscana lariophaga* and the larval-1pupal parasitoid *Dinarmus basalis* on Callosobruchus maculates populations and cowpea losses. Entomologia Experimentalis et Applicata. 2002; 104:289-297.
105. Vanmathi Shifa J, Padma Latha C, Ranjit Singh AJA. Impact of entomopathogenic fungus, *Beauveria bassiana* on stored grains pest, Callosobruchus maculates (F.) (Coleoptera: Bruchidae). Journal of Biopesticides. 2011; 4(2):194-197.
106. Wang S, Ikediala JN, Tang J. Radio frequency treatments to control codling moth in in-shell walnuts. Postharvest Biology and Technology. 2001; 22(1):29-38.
107. Yu JC, Jiang ZT, Li R, Chan SM. Chemical composition of the essential oils of *Brassica juncea* (L.) Coss. grown in different regions, Hebei, Shaanxi and Shandong, of China. Journal of food drug analysis. 2003; 11:22-26.