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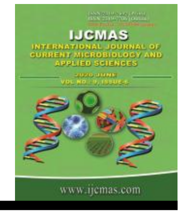

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Botanicals as Eco-Friendly Biorational Alternatives of Bio Insecticide against *Callosobruchus Maculatus* (F.) (Coleoptera: Bruchidae) Stored Pulses - A Review

K. Govindan[1*], S. Geethanjali[2], S. Douressamy[1], M. Pandiyan[3] and G. Brundha[1]

[1]Department of Crop Protection, [2]Department of Crop Improvement
[3]Department of Plant Breeding and Genetics, Agricultural College and Research Institute, Valavachanur – 606 753, Thiruvannamalai District, Tamil Nadu, India
**Corresponding author*

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The presents review article has been reviewed to know the importance of different plant products (botanicals) against *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) the potential insecticidal botanicals in the management in storage condition and infesting the various stored pulses such as (black gram, greengram, cowpea, Bengal gram, Mmung bean etc). *Callosobruchus maculatus* is one of the most serious pests brought into storage containers with harvested black gram that can cause total loss of the stored crop in a few months. The estimated post-harvest losses caused by bruchids to the pulses ranged from 30-40% within six months and when left unattended losses could be up to 100 per cent. Pulse beetles, *C. maculatus* are the most serious pests in stored legumes in majority of tropical countries. Botanicals have been used since time immemorial for protection of stored products against common pests. They acts as repellents, antifeedants, toxicants and behave as natural grain protectants by behaving as chemosterilants/reproduction inhibitors or insect growth and development inhibitors. Attention has been given to the possible use of plant products or plant dry powders as promising alternatives to synthetic insecticides in controlling insect pests of stored products. Different botanicals and it is formulations have been reported time to time showing pronounced insecticidal activity, repellence to pest, oviposition deterrency, adult emergence inhibition, ovicidal, larvicidal, pupaecidal activity and feeding deterrency based on their contact toxicity and fumigation effects. Botanicals are biodegradable, non-residual, equally effective and easily available botanicals, cost effective and non-toxic to natural enemies. Some botanicals have also been practically proved efficacious to protect the stored food commodities from the bruchids during storage conditions. Hence, they may be recommended in food security programmes as eco-friendly and biorational alternatives of synthetic insecticides providing integrated management of the losses of stored food commodities due to infestation of bruchids.

Introduction

Pulses are also known as “Poor man’s meat, Pulses are an important part of the vegetarian diet of Indian subcontinent, being a rich source of protein (20–30 %) and high nutritional value, offer the most practical means of solving malnutrition in our country

(Rupesh *et al.,* 2016). India has achieved first rank in World area (35 %) and production (25%) under Pulses; India has an area of about 25 million ha of pulses producing 16.5 million tonnes of Pulses. This is 35% percent of the world area and 25% of world production (Rupesh *et al.,* 2016). However, the average yield level in India is 650 kg/ha against the world average of 909 kg/ha. In Tamil Nadu, Black gram (46%) and Green gram (25%) are the major Pulse crops accounting for about 71 percent of the area under Pulses and the average yield level is far below the national average. Tamil Nadu, Black gram (46%) and Green gram (25%) are the major Pulse crops accounting for about 71 percent of the area (Vasanthakumar, 2016).

Per capita requirement of Pulses (60 gm for male and 55 gm for female) is less than the availability (42 gm). Globally, India stands first in terms of area and production of Pulses. Black gram is (4.05 lakh ha), Production (3.10 lakh tonnes) and Productivity (851 kg/ha) (Vasanthakumar, 2016). Black gram and green gram account for about 71 per cent of the area in Tamil Nadu (Vasanthakumar, 2016). Black gram *Vigna munga (L.)*, an important legume crop suffers losses both qualitatively and quantitatively due to the attack by bruchids in the post-harvest stages (Raghu *et al.,* 2016).

All the pulses seeds should be stored to meet home consumption as well as for sale. Major constraints for the production and protection of pulses are pest infestation in the field and in storage. Infestation begins in the field but causes serious damage to the seeds during storage (Sanon *et al.,* 2018). Major constraints for the production and protection of pulses are pest infestation in the field and in storage (Manju *et al.,* 2019). Stored product pests are a great challenge in our economy because they infect and contaminate stored agricultural products and animal feed (Jacobs *et al.,* 2019). Stored products are frequently damaged by insect pests and this may account to 5-10% in temperate zones and 20-30% in the tropics (Nakakita, 1998). The post-harvest losses and quality deterioration caused by storage pests are major problems throughout the world. Pulse beetle is the most serious pest in stored legumes in majority of tropical countries (Ratnasekera and Rajapakse, 2012).

Among the insect pests of various pulses crops, pulse beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) is a cosmopolitan field-to-store pest ranked as the principal post-harvest pest, which lead to a reduction of commercial value and seed germination, in addition the grains become unfit for human consumption (Atwal and Dhaliwal, 2005). Infestation begins in the field but causes serious damage to the seeds during storage (Kayode and Ileke, 2019). Bruchids are known to inflict quantitative and qualitative losses to stored pulses (Soe *et al.*, 2020). Several pulses is seriously infested by pulse beetles *C. maculatus* all over the world (Dimetry *et al.*, 2002; Ahmed, 2010; Hafez *et al.*, 2013).

At present, pest control measures in storage rely on the use of synthetic insecticides and fumigants, which is the quickest and surest method of pest control but it is also not advised to mix the insecticides with food grains. Their indiscriminate use in the storage, however, has led to a number of problems including insect resistance, toxic residues in food grains (Fishwick, 1988), environmental pollution (WMO, 1995) and increasing costs of application. In view of these problems together with the upcoming WTO regulations, there is a need to restrict their use globally and implement safe alternatives of conventional insecticides and fumigants to protect stored grains from insect infestations (Yusof and Ho, 1992; Subramanyam and

Hagstrum, 1995). Pesticides to control pest outbreaks remains high (Farrar *et al.,* 2016; Vasileiadis *et al.*, 2017).

Many synthetic insecticides have been found effective against stored product pests but proved to be hazardous to men and domestic animals. The over reliance on and non-judicious use of synthetic pesticides especially insecticides since last four decades led to wide spectrum of pests problem like pests resistance to chemicals, resurgence of pests, residues in food and soil and risks to human and animal health, besides environmental pollution (Mohapatra and Gupta, 1998). Musa and Uddin (2016) reported that many plants possess activities against stored grain pests. To solve this problem, many researchers have discovered alternative pest management products derived from plants (Isman, 2013).

The insecticidal constituents of many plant powders are due to their enrichment of phytochemicals such as alkaloids, tannins, and flavonoids (Afolabi *et al.*, 2018). Plant products are cheap and are easily accessed by farmers and small-scale industries in the form of crude or partially purified extracts. It was indicated that mixing storage pulses and plant products such as leaf, bark, powder or extracted oils reduced the oviposition rate, inhibited the adult emergence of bruchids and decreased the seed damage rate (Onu and Aliyu, 1995; Shaaya *et al.*, 1997; Keita *et al.*, 2001; Tapondjou *et al.*, 2002; Govindan and Nelson, 2007; Ahmed, 2010; Islam *et al.*, 2013; Musa and Adeboye, 2017; Sanon *et al.*, 2018 ; Manju *et al.*, 2019; Soe *et al.*, 2020).

In the storage period, pulse beetles are managed by using synthetic insecticides, vegetable oils, plant powder and inert materials. The use of natural plant products as insecticide is gaining importance in recent years due to ill effects of synthetic insecticides such as pest resistance, pest resurgence, and pest residues in food and pollution. The botanicals are easily biodegradable and ecologically compatible without posing environmental pollution. Hence, many scientists are doing research work on the effect of various plants on pulse beetle and other stored products insects. The research works carried out based botanicals by several scientists works reviewed and presented under the following sub headings.

Losses caused by *Callosobruchus maculatus*

Insecticidal action of botanicals on *Callosobruchus maculatus*

Effect of botanicals on oviposition, egg hatching and adult emergence of *Callosobruchus maculatus* and seed weight loss.

Losses caused by *Callosobruchus maculatus* in pulses

Pulses are annual and seasonal crops that can be stored for several months. However, these are at high risk of damage due to post harvest losses which can be up to 25-50 per cent (Lal and Verma, 2007), These losses are linked to insufficient and poor storage facilities, lack of knowledge of advanced technology in post-harvest pulse management and harsh climatic conditions particularly in developing countries like India (Singh and Larson 2016). During storage, pulse beetles or bruchids attack the pulse seeds and *Callosobruchus chinensis* L. and *Callosobruchus maculatus* F. are common bruchid species. These bruchids causes about 5-10% losses during storage (Lal and Verma, 2007). These losses vary widely in different climatic conditions, pulse varieties, geographical locations and processing and storage techniques.

The pulse beetle, *C. chinensis* and *C. maculatus* are the two important species of pulse beetle. The loss caused by the pulse beetles has been variable. The loss caused by pulse beetle *C. chinensis* was up to 55.20 per cent in chickpea (Ramsingumrao and Verma, 2003). Sridharan and Venugopal (1994) stated that *C. maculatus* could spoil the quality of black gram seeds by as much as 100 per cent. Feeding by half-mature larvae of *C. maculatus* often lead to most noticeable decline in germination in pulse seeds (Yadava and Bhatnaga, 1987). Singh and Sharma (1982) observed that the damage caused by *C. maculatus* and the loss of germination was significantly higher in green gram than in black gram after five months of storage. Caswell (1973) reported that annual losses of cow pea in Nigeria due to *C. maculatus* was 2900 tons (dry weight). *C. maculatus* is one of the most serious pests brought into storage containers with harvested black gram that can cause total loss of the stored crop in a few months (Dongre *et al.*, 1996). The estimated post-harvest losses caused by bruchids to the pulses ranged from 30-40 per cent within 6 months and when left unattended losses could be up to 100 per cent (Dongre *et al.*, 1996; Mahendran and Mohan, 2002).

Callosobruchus spp. can cause damage of legume seeds up to 100 % during storage In Thailand (Gbaye *et al.*, 2011). Gujar and Yadav (1978) recorded 32.2 to 55.7 per cent loss in seed weight and 17.0 to 53.5 per cent loss in protein content. The insect spends its entire immature stage in individual legume seeds, where they cause weight loss, decrease in germination potential increase in moisture, free fatty acid levels, decrease in protein contents.

Insecticidal action of botanicals on *callosobruchus maculatus* (F.)

Insecticidal action of *piper nigrum* on *C. maculates*

Piper nigrum L. seed is well known for its insecticidal properties against *Callosobruchus maculatus*. *Piper nigrum* have active compound called Piperine is a major active principle compound found in seeds and it is the responsible for the killing the *C. maculatus* (Swamy and Raja, 2018). Govindan *et al.*, (2010) who found that *P. nigrum* dust formulation (Pn10D) was prepared by mixing pulverized seed powder of *P. nigrum* (10%) and fly ash (90) (Pn10D) at 4.00 percent caused cent percent mortality of *C. maculatus* after 72 hr after the treatment. Islam *et al.*, (2013) found that *P. nigrum* 1g/kg gram seeds showed 100.00 per cent mortality to *C. maculatus*. Rajapakse, (1990) observed that *P. nigrum* 2 per cent coated seeds showed cent per cent mortality to *C. maculatus.* Hussain and Rahman, (2008) stated that *P. nigrum* seed powder causes 100 per cent mortality to *C. maculatus* within 24 hrs after treatment. Abdullah *et al.*, (2017) observed black pepper, *P. nigrum* caused highest mortality at 24 hr (98.3%) at 48 hur after treatment (100.0%) to *C. maculatus.* Chudasama *et al.*, (2015) refer that *C. maculatus* with 5 per cent black pepper seed extract treated with green gram very effective and controlling the *C. maculatus.* Manju *et al.*, (2019) observed that *P. nigrum* one per cent treated green gram seeds resulted in 100 mortality to *C. maculatus* within 12 h after treatment. Shah and Mahdi, 2016 observed that *P. nigrum* seed powder highly toxic to *C. maculatus.* Mixing of 1 per cent seed powder of *P. nigrum* resulted in 100 per cent mortality to *C. maculatus* within 12 hr (Manju *et al.*, 2019). Rathod *et al.*, (2019) observed that black pepper powder 3g/kg of green gram seeds results showed cent per cent mortality two days after treatment . Several scientists reported their efficacy of black pepper, *P. nigrum* seed powder and their toxicity to adults of *C. maculatus*. (Govindan and Nelson , 2007; Shukla *et al.*, 2009; Singh 2011; Islam *et al.*, 2013 ; Mahdi *et al.*, 2016; Swamy and Raja, 2018 ; Rathod *et al.*, 2019; Emeasor and Chukwu, 2019).

Insecticidal action of *piper guineense* on *C. maculatus*

Piper guineense powder (0.1g/20g) admixed with cowpea caused 100 per cent mortality to *C. maculatus* adult (Ivbijaro and Agbaje, 1986). Extract of *P. cubeda* fruit when applied topically caused 87 per cent mortality of *C. maculatus* (Su, 1990). Mbata and Ekpendu (1992) reported that *P. guineense* seed powder caused high mortality of *C. maculatus* even at low concentration. Lale (1992) reported that *P. guineense* powder at 1.5 g/20 g cowpea seeds caused 96 per cent mortality of *C. maculatus* adult when assessed at 48 hours. The insecticidal properties of *Piper guineense* could be attributed to the presence of piperine (Oparaeke, 2006). Abdullahi and Muhammad (2004) reported that *P. guiennese* at 1 g per 50 gram cowpea seed caused 100.00 per cent mortality of *C. maculatus*.

Insecticidal action of *acorus calamus* on *C. maculatus*

Acorus calamus have high insecticidal activity due to active compound called β-asarone (cis-2, 4, 5-trimethoxy-1-propenylbenzene) is a sesquiterpenoid, is a major active principle found in oil of the rhizomes and it is the responsible for the killing the *C. maculatus* (Shreelaxmi *et al.*, 2017). The rhizomes of *A. calamus* possess antibacterial, bio pesticide and antifungal properties (Rani *et al.*, 2003). Su (1991) reported that topical application of *A calamus* oil at 30 µg per insect caused 98 per cent mortality of *C. maculatus*. The sweet flag powder mixed with red gram seeds at 1.5 and 2.5 g per 5 g seeds gave protection up to three generations of *C. maculatus* (Shivanna *et al.*, 1994). Govindan and Nelson, (2007) stated that *Acorus calamus* rhizome powder 2 per cent showed 100 per cent mortality to *C. maculatus* two days after treatment. *Acorus calamus* rhizome acted as a contact or stomach poison, or antifeedant and repellent on the newly emerged adults of *C. maculatus* (Dhivya *et al.*, 2019). Saranya *et al.*, (2019) who concluded that *A calamus* hexane extract at 0.1per cent treated cowpea seeds resulted cent per cent mortality to *C. maculatus* after five days after treatment. Rathod *et al.*, (2019) reported that *A. calamus* rhizome powder 10g/kg of green gram seeds cent per cent mortality to *C. maculatus* . Several scientists tested their efficacy of sweet flag, *A. calamus* rhizome powder against the adults of *C. maculatus* (Chanpark *et al.*, 2003; Shukla *et al.*, 2009; Chandel *et al.*, 2018; Shreelaxmi *et al.*, 2019; Dhivya *et al.*, 2019).

Insecticidal action of *azadirachta indica* on *C. maculatus*

The insecticidal properties of *Azadirachta indica* could be attributed to the presence of azadirachtin (Oparaeke, 2006).Cowpea seeds 20g treated with 1-3 g of dry neem (*A. indica)* seed powder protected the seed from *C. maculatus* for more than 4 months (Ivbijaro, 1983). Sowunmi and Akinnusi (1983) reported that the powdered neem seed kernels mixed with stored cowpea seeds at 1.0 to 2.0 parts per 100 parts of cowpea seeds was effective for eight months. Tanzubil *et al.*, (1987) found that the neem fruit dust at 10 per cent w/w protected cowpea seeds for 4 months from *C. maculatus*.

Tenzubil (1991) reported that the Neemazal – W powder (500 ppm) caused 97.8 per cent mortality of *C. maculatus* adults one day after the treatment. *Melia azedarach* fruit powder was also toxic to *C. maculatus* (Lakwah *et al.*, 1999). Singh *et al.*, (1994) reported that both neem leaves and seed powder mixed with cowpea seeds at 3 per cent (w\w) caused 85 – 90 per cent mortality of *C. maculatus.* Kumari and Kumar (1998) also observed that neem leaves and seed powder mixed with cowpea seeds at 3 per cent w/w caused 85 – 90 per cent mortality of *C. maculatus* adults. Neem oil 2 per cent was very effective against *C. maculatus* (Paneru and Sivakoti, 2001). Akunne *et al.,* (2013) who concluded *A. indica* leaf powder was also toxic to *C. maculatus*. Neem leaf powder protection from pulse beetle infestation in mung bean (Ahmad *et al.,* 2015).

Insecticidal action of others botanicals against *C. maculatus*

Several researchers tested, documented the various plant species against *C. maculatus* and presented here. Banja and Maboganje (1999) reported that leaves and seed extracts of *Jatropha curcas* was most effective against *C. maculatus*. The seed powder of *Dennettia tripetala* 1 per cent caused 100 per cent mortality of *C. maculatus* with in 72 hours (Umoetok and Okokon, 1999). Eltayeb and Elhag (2000) observed that one per cent crude extract of *Rhazya strica* leaves showed 82 per cent repellency for *C. maculatus.*

Application of *Chenopodium ambroisoides* 5.0 per cent extract caused 54 per cent mortality of *C. maculatus* adults (Kehinde *et al.,* 2002). Insecticidal activity of *Tephrosia vogelli* against *C. maculatus* was reported by Sara (2004). Mollah and Islam (2005) reported that leaf, stem and root of *Murraya paniculata* extracted in four different solvents *viz.,* petroleum ether, ethyl acetate, acetone and methanol were toxic to *C. maculatus.* Ratnasekera and Rajapakse, (2012) found that extract of *A. squamosa* was toxic to adults beetles of *C. maculatus* .

Islam *et al.,* (2013) who observed that the black pepper was effective inhibit the oviposition in *C. macultus*. The leaf powder of *Ocimum gratissimum* was more effective in causing *C. maculatus* mortality (Felicia *et al.,* 2013). Vojoudi *et al.,* (2014) showed that *Mentha pulegium* essential oil was more effective against *C. maculatus*. Black pepper powder possesses high anti-ovipositional potential (Upadhyay and Jaiswal, 2007; Ahmed *et al.,* 2011). Kosini and Nukenine (2017) which reported that *Gnidia kaussiana* leaf powder highest mortality to *C. macultus.* Mojisola *et al.,* (2016) stated that *Citrus sinensis* was able to achieve 100 per cent mortality *C. maculatus* at the third hour of exposure. Fotso *et al.,* (2018) observed that *H. welwitschii* leaves powder caused highest mortality to *C. maculatus* in stored cowpea. *Eugenia aromatica* @ 1 g/20 g admixed cow pea seeds and caused 100 per cent mortality with in 24 hrs (Jacobs *et al.,* 2019). Manju *et al.,* (2019) are found that all the twelve botanical powders were significantly effective against *C. maculatus* insect. Antifeedant deterrent effect showed *Alium sativum* (61.6%) and *Mondora myristica* (64.9%) to *C. macultus* (Egwunyenga and Ake, 2019).

Edwin and Anigboro (2019) stated that *A. sativum* and *M. myristica* caused a repellency of 50.3 and 49.9 45.5 per cent to *C. maculatus* Yusra, (2020) stated that *Piper Cubeba* seed powder at 4g / kg mung bean seeds caused 100 per cent mortality seven days after exposure to *C. maculatus.* Leaves extract of *Hyptis suaveolens, Alstonia boonei,* and *Tephrosia vogelii* were tested and highly toxic to *C. maculatus* (Ehimemen and Salisu, 2020).

Effect of botanicals on oviposition, egg hatching and adult emergence of *callosobruchus maculatus* (F.) and seed weight losses

Oviposition

Eltayeb and Elhag (2000) observed that *P. nigrum* reduced the egg laying by *C. maculatus.* Kehinde *et al.,* (2002) reported the ovicidal and oviposition deterrent activities of Chenopodium ambroisoides. *N. tabacum, T. vogelli* and *Securidaca longepedonculata* significantly reduced the number of progeny of *C. maculatus* (Boeke *et al.,* 2004). Rajapakse and Vantmden (2004) studied the effect of oil of corn, groundnut, sun flower and sesame and found that they significantly reduced oviposition of *C. maculatus*. Leaf powder of *Momordica charantia* prevented loss of weight of stored cowpea caused by *C. maculatus* (Sara *et al.,* 2004). Rajapakse and Vantmden (2004) reported that powder of *C. citratus, Cinnamomum camphora* and *Derris indica* reduced egg laying by *C. maculatus.* Sara *et al.,* (2004) observed the with *Ocimum basilucum* leaf powder suppress the eggs of *C. maculatus.*

Govindan *et al.,* (2010) who found that *P. nigrum* dust formulation (Pn10D) was prepared by mixing pulverized seed powder of *P. nigrum* (10%) and fly ash (90) (Pn10D) at 4.00 percent was most effective in reducing the oviposition of *C. maculatus.* Singh, (2011) reported that garlic clove powder acted as best ovipositional deterrent against *C. maculatus* in chickpea. Idoko and Adesina (2012) who reported that *P. guineense* caused the mortality of *C. maculatus* adults and eventual suppression of progeny emergence due to contact toxicity of the powder. Oils of *Ocimum sanctum* at 1.5 µl completely inhibited egg laying of *C. maculatus* (Ratnasekera and Rajapakse, 2012). Devi and Devi (2013) reported the reduction in oviposition of *C. maculatus* in gram treated with neem powder. Gupta *et al.,* (2015) who reported the efficacy of neem leaf powder in reducing oviposition against *C. maculatus* on green gram seeds.

Mojisola *et al.,* (2016) *Azadirachta indica* (neem) leaf extracts were toxic to adult *C. maculatus* and prevented egg hatching. Neem leaf powder (*A. indica*) applied @ 1.5mg/100g seeds of mungbean decreased total progeny by 38 per cent (Ahmad *et al.,* 2015). Gupta *et al.,* (2015) who reported the efficacy of neem leaf powder in reducing oviposition against *C. maculatus* on green gram seeds. Chudasama *et al.,* (2015) refer that aqueous extracts of plants materials, maximum percentage of (67.19%) oviposition deterrence was observed in custard apple seed extract. Minimum number of eggs (3.11 eggs/ 5 females) was laid by 5 pairs of *C. chinensis* in sweet flag plant powder (Kaur *et al.,* 2019). Rathod *et al.,* (2019) who found that *O. canum* leaf powder @ 3g / kg of green gram treated seeds results showed less numbers of eggs were laid.

Manju, *et al.,* 2019 stated that *Piper nigrum* 1 per cent seed powder treated green gram seeds sowed highest percentage of oviposition deterrence (71.6 %) in *C. macultus*. Sathyaseelan *et al.,* (2008) who observed that *Ocimum canum* leaf powder at 5 per cent treated green seeds and caused 68.70 per cent mortality to *C. maculatus.* The *Eugenia aromatica* @ 1 g/20 g admixed cow pea seeds complete inhibit the oviposition in *C. macultus* (Jacobs *et al.,* 2019). Niranjana and Karunakaran (2019) stated that *A. indica* 10 per cent leaf powder was found to be the very effective reducing the oviposition by *C. macultus*. Ehimemen and Salisu, (2020) who reported that leaves extract of *Hyptis suaveolens, Alstonia boonei* and *Tephrosia vogelii* inhibit the egg laying in *C. maculatus*.

Adult emergence

Raja *et al.,* (2000) observed that cowpea seeds treated with 0.5 and 1 per cent methanol and aqueous extract of *Vitex negundo* significantly reduced the number emergence of F1 adults of *C. maculatus.* Tapondijou *et al.,* (2002) reported that powdered leaves of

Chenopodium ambrosiodes inhibited F1 progeny production and adult emergence. Abdullahi and Muhammad (2004) reported that *P. quineense* fruit powder at 1g per 50 g cowpea seed inhibited the oviposition by 26 per cent and adult emergence by 50 per cent in case of *C. maculatus.* Swella and Mushobozy (2007) who individually reported *Annona senegalensis* seed powder had high toxic to oviposition and progeny development by protecting cowpea seeds against the *C . maculatus* infestation. Govindan and Nelson (2008) who reported lower adult emergence of *C. maculatus* in seeds treated with sweet flag powder. *Piper guineense* reduced adult emergence of *C. maculatus* (Emeasor and Chukwu, 2019).

Plant powders causes sterility to male beetle, thus made the females produced non-fertile eggs (Ojianwuna and Umoru, 2010). Govindan *et al.,* (2010) who found that *P. nigrum* dust formulation (Pn10D) seed powder of *P. nigrum* (10%) and fly ash (90) (Pn10D) at 4.00 percent was most effective in reducing the adult emergence of *C. maculatus.* Neem leaf powder (*A. indica*) applied @ 1.5mg/100g seeds of mungbean decreased total progeny by 38 per cent (Ahmad *et al.,* 2015). Oils of *Ocimum sanctum* at 1.5 µl completely inhibited adult emergence of *C. maculatus.* (Ratnasekera and Rajapakse, 2012). Rupesh *et al.,* (2016) reported that *Neem* oil @10ml/kg of pigenonpea seeds completely inhibited oviposition and adult emergence of *C. maculatus*.

Piper nigrum 2g of powder admixed with 20 g of mung bean seeds resulted complete inhibit the adult beetle emergences of *C. macultus* (Emeasor and Chukwu, (2019) ; Manju *et al.,* 2019; Rathod *et al.,* 2019). Kaur *et al.,* (2019) who stated that neem leaf powder 5 g / 100 g of pea seed was highly effective and inhibit the adult beetle emergence. Swamy and Raja (2018) stated that mixing of black pepper powder @ 0.1, 0.2 and 0.3 per cent treated seeds of green gram were also found significantly effective as very negligible numbers (0.33, 1.0 and 8.33 adults respectively) emerged. The *Acorus calamus* rhizome powder @ 10g/kg of green gram treated seeds results showed that no emergence of *C. maculatus* (Rathod *et al.,* 2019). Jacobs *et al.,* (2019) who found that *Eugenia aromatica* @ 1 g/20 g admixed cow pea seeds complete inhibit the adult emergence of *C. macultus*. Reduced no adult emergence with *O. sanctum* leaf powder (Ratnasekera and Rajapakse, 2010).

Reduction in the F1 progeny emergence of *C. maculatus* in the Bambara groundnut treated with *Ocimum canum* powder (Kosini *et al.,* 2015). Chudasama *et al.,* (2015) observed the maximum percentage (78.45%) adult emergence reduction was reported in custard apple seed extract. Mahama *et al.,* (2018) reported that significant reduction in the progeny F1 production of *C. maculatus* on seeds treated with *Eucalyptus camaldulensis* leaf extracts on Bambara groundnut grains**.**

Saranya *et al.,* (2019) reported that *A calamus* hexane extract at 0.05, 0.07, 0.09 and 0.1per cent concentrations treated cow pea seeds were no progeny development of *C. maculatus*. Niranjana and Karunakaran (2019) stated that *Annona squamosa* 10 per cent could be considered as potential plant extracts against *C. maculatus*. Leaves extract of *Hyptis suaveolens, Alstonia boonei* and *Tephrosia vogelii* the reduced the number emergence of F1 adults of *C. maculatus* (Ehimemen and Salisu, 2020).

Seed weight loss

Aslam *et al.,* (2002) found lower weight loss when chickpea was treated with clove and balck pepper extract. Swella and Mushobozy

(2007) refer that Black pepper (*Piper* spp.) powder and coconut oil showed good potential in protecting cowpea seeds against bruchid damage. Govindan *et al.,* (2010) who found that *P. nigrum* dust formulation (Pn10D) seed powder of *P. nigrum* (10%) and fly ash (90) (Pn10D) at 4.00 percent was most effective against *C. maculatus* and reducing the seed weight loss in stored black gram. Dauda *et al.,* (2012) who stated that *Alium sativum* oil as grain protectant in cowpea and reduced seed weight loss and up to three monthsof storage. Udo and Harry (2013) reported that groundnut oil protecting cowpea up to six months of storage period. The botanicals as *Curcuma longa*, *Zingiber officinale* and *Z. officinale* had effective and reduced the seed weight loss in cowpea (Asawalam and Anaeto 2014).

Poornasundari and Daniel (2015) found black pepper powder at doses of 0.5, 1.0, 1.5 and 2.0 g mixed with 40 g of green gram as effective and protection up to six months of storage period. Custard apple leaf powder 2 per cent coated with black gram seeds results showed less infestation of pulse beetle (Suthar and Bharpoda, 2016).

Swamy and Raja (2018) stated that mixing of black pepper powder @ 0.1, 0.2 and 0.3 per cent treated seeds of green gram very effective and reducing the seed weight loss. Jumbo, *et al.,* (2018) showed that oil dosage of Clove and Cinnamon proportionately reduced the losses in bean weight caused by *C. maculatus*

The green gram seed damage due to pulse bruchids was nil in pepper powder @ 0.4 and 0.3 per cent treated seeds (Swamy and Raja, 2018). Rathod *et al.,* (2019) who stated that black pepper powder causes less infestation and least weight loss noticed. Kaur *et al.,* (2019) stated that no seed damage and weight loss was recorded in pea seeds treated with sweet flag powder at 3g/100g and 5g/100g doses. Minimum grain loss was noted with black pepper @ 1.00 g/kg (Islam *et al.,* 2013). Minimum weight loss percentage was observed in the cowpea seeds treated with custard apple seed extract at 5per cent Chudasama *et al., (*2015).

Yusuf, *et al.,* (2019) stated that cowpea seeds treated with *A. indica, P. guineense, C. citratus*, ranging between 1.88 and 2.09 per cent seed weight loss Niranjana and Karunakaran (2019) stated that *A. indica* 10 per cent leaf powder was reducing the seed weight loss in black gram. Saranya *et al.,* (2019) stated that *A. calamus* hexane extract at 0.05, 0.07, 0.09 and 0.1per cent concentrations treated cow pea seeds were no seeds weight loss recorded. Leaves extract of *Hyptis suaveolens*, *Alstonia boonei* and *Tephrosia vogelii* tested against *C . maculatus* and protect the stored cowpea seeds from its infestation (Ehimemen and Salisu, 2020).

After reviewing findings of several researchers it can be concluded that *piper nigrm , Piper guineense Acorus calamus, Azadirachta indica* and other many plants have insecticidal properties had very effective against *Callosobruchus maculatus viz.,* insecticidal action (mortality), oviposition, adult emergence and seed weight loss. Insecticidal toxicity of plant and their alkaloids responsible and found be toxic pulse beetle *C. maculataus*.

Many authors have evaluated the insecticidal (grain protectant) properties of plant products on various species of stored product insect pests. The results clearly show that it is possible to develop methods for grain protectants with reduced use of synthetic chemical insecticides.

The main advantages of botanical pesticides are ecofriendly, easily biodegradable, nontoxic to non-target organisms, and many plant-derived natural products acting against insects could be produced from locally available raw materials. They have been numerous botanical pesticides studied at the laboratory level. Therefore, the resource poor farmers can use botanicals controlling pulse beetle is stored black gram as they may not afford to buy chemical pesticides due to high cost. Furthermore, the use of botanical pesticides to control pulse beetle is an appropriate strategy to avoid environmental pollution and other hazards, since the chemical pesticides are used by farmers and in agro industries currently. The insecticides of plant origin could be exploited for the development of novel molecules with highly precise targets for sustainable insect pest management in stored grain.

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