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Management of maize weevil, *Sitophilus zeamais* (M.) using indigenous plant extracts at medium altitude hills of Meghalaya

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ABSTRACT

Different indigenous plant products in the form of plant powders (dust) were evaluated at different doses for management of maize weevil, *Sitophilus zeamais* (M.) under laboratory conditions at ICAR Research Complex for NEH Region, Umiam, Meghalaya. The plants included Persian lilac (*Melia azaderach*), lantana (*Lantana camera*), nishinda (*Vitex negundo*), *Datura species,* papaya (*Carica papaya*), *Eupatorium odoratum*, tulsi (*Ocimum* spp.) and goat weed (*Ageratum conyzoides*). Amongst different plant powders, lantana powder proved to be most effective followed by melia leaf powder @ 5g/100g grain. Highest adult cumulative mortality (100 %) was observed in grains treated with lantana powder and the least mortality was obtained in tulsi treated grains. The lowest grain damage was recorded in maize grains treated with lantana leaf powder treatment and was at statistically at par with melia treated grains ($P < 0.05$). The highest weight loss was recorded in tulsi leaf powder (6.19 %) which was statistically at par with Eupatorium treated grains (5.70 %). All the plant powders were found superior over control treatment.

1. Introduction

Maize (*Zea mays* l.) belongs to the family *Poaceae* or Gramineae. Maize is a cereal grass related to wheat, rice, oat and barley. It is the third important food crop after wheat and rice. Because of the various advantages derived in cultivating the crop, maize is referred as "The Queen of Cereals". Aside from being one of the major sources of food for both human and animals, it is also processed into various food and industrial products including starches, sweeteners, oil, beverage, industrial alcohol and fuel ethanol (Garcia 1990).

After the harvest grains are necessarily stored for consumption. Farmers retain about 70 per cent of their agricultural produce for seed purpose, consumption and for sale (Reddy and Pushpamma 1980). Post harvest losses are enormous in developing countries as compared to developed countries. About 5-40% per cent of food grains are lost to various biotic and abiotic factors (Girish *et al.*, 1985; Haque *et al.*, 2000; Raja *et al.*, 2001). Cereal pests may infest the corn grain during storage and transport. Weevils from the genus *Sitophilus* are major pests of stored maize all over the world (Grenier *et al.*, 1994). Between the two species of *Sitophilus viz.*, *Sitophilus zeamais* (Motsch.) and *Sitophilus oryzae* (Linn.), the former causes substantial losses to stored corn up to 18.30 per cent (Adams 1976). Worldwide seed losses ranging from 20-90 per cent have been reported due to maize weevil (Giga *et al.,* 1991; Delima 1987). *Sitophilus zeamais* (M.) is reddish brown to black coloured weevil measuring about 3-4mm long. In maize or sorghum, attack may start in the mature crop when the moisture content (MC) of the grain has fallen to 18-20%. Subsequent infestations in store result from the transfer of infested grain into store or from the pest entering into storage facilities, probably attracted by the odour of the stored grain. In stored maize, heavy infestation of this pest may cause weight losses up to 30-40%, although losses are commonly 4-5% (Sclar 1994). This evidently indicates the importance of *S. zeamais* in storage of maize. They devour the seed completely from inside make them chaffy; and eventually seed viability is lost (Hill 2002). Infestation of these insect pests further result in mold formation (Magan *et al.*, 2003); development of *Aspergillus*, (a fungus producing mycotoxins) which is the most powerful carcinogen in humans and animals (Williams *et al.,* 2012; Carrieri *et al.*, 2013) and phytotoxicity to grain (Lee *et al.*, 2003).

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Prevention of losses in stored products due to insects is of paramount importance. Controlling stored pests is a daunting task, although synthetic chemicals may play a significant role in reducing storage losses due to insect pests (Tapondjou *et al.*, 2001). However, their current applications for the control of storage insect pests is limited because of resistance development by the insects (Subramanyam and Hagstrum 1995; Arthur 1996; Mohan *et al.*, 2010; Correa *et al.*, 2011) consumers concern, widespread environmental hazards and increasing costs of application (Bekele *et al.*, 1996; Bekele 2002). There is a need to find the alternatives to chemicals that can effectively prevent the storage losses, easily available, affordable, safer and least detrimental to the environment. Plant-derived pesticides can be transferred into practical applications in natural crop protection which can help the small-scale farmers (Binggeli 1999). It is an age old practice to mix local plants with grains. The use of botanical pesticides to protect plants from pests is very promising because of several distinct advantages. Substances of plant origin are more biodegradable, low toxicity to human beings; and there is every possibility of maintaining environmental conditions inside the storage systems (Guzzo *et al.*, 2006). Many researchers have worked on management of stored insect pests on maize using plants products (Binggeli 1999; Mulungu *et al.*, 2007; Nukenine *et al.*, 2011; Lakshmi Soujanya *et al.*, 2012; Lakshmi Soujanya *et al.*, 2013; Shiberu and Negeri 2017; Hakeem *et al.*, 2017; Basyal *et al.*, 2022; Tiwari *et al.,* 2018). North-eastern region of India is also known to be one of the hotspot of biodiversity of the world and so far little work has been done on this aspect, therefore, there is a wide scope for utilizing plant products as grain protectants against *S. zeamais* which is most prevalent in this region. The efficacy of different plant powders on mortality, adult emergence, grain damage and grain weight loss are presented and discussed in this paper.

2. Materials and methods

The studies were conducted in the Entomology Laboratory, ICAR Research Complex for NEH Region, Umiam, Meghalaya to evaluate the different plant extract (powder) against maize weevil.

Preparation of leaf powder

Fresh leaves of Persian lilac *(Melia azedarach),* lantana (*Lantana camera*), nishinda (*Vitex negundo), Datura species,* papaya (*Carica papaya*), *Eupatorium odoratum*, tulsi (*Ocimum* spp.*)* and ageratum *(Ageratum conyzoides)* were collected from the fields of ICAR Research Complex for NEH Region and these leaves were shade dried for 14 days so that no moisture would be present. Dried leaves were then grounded to powder using electric grinder and passed through 0.25 mm (250 μm) pore size mesh sieve to obtain uniform fine dust powder. The different powders obtained from different plants were kept in different plastic containers in an airtight condition.

Bioasssay with different plant powders

Maize grains were used for testing the bioefficacy of different plant powders. Different quantities *viz.*, 1, 3, and 5g of each plant powders was added to separate plastic jars of 1 litre capacity, each containing 100 gram maize grains and was mixed thoroughly. The mouths of the jars were covered with aluminium foil having pin holes on it to permit aeration and prevent the escape of the weevils. Malathion @ 5 per cent was used as a conventional insecticide and a control was also maintained without any treatment for comparison. Three replications were taken for each treatment. Ten pairs of randomly selected 0 - 24 hour old adult weevils were transferred to the jars containing maize grains treated with different concentrations of plant powders.Mortality of adults, 1 day before treatment and at 1, 3, 7, 14 and 24 days after treatment (DAT) was recorded for all the treatments. Number of adults emerged and test insect survived were also noted for all the treatments. Per cent damage in all the treatments was also recorded by counting the number of damaged seeds and number of holes made by the weevils.The per cent weight loss was calculated by using count and weigh method of Senguttuvan *et al.* (1995)

$$\text{Weight loss} = \frac{(U.\,Nd)-(D.\,Nu)}{U(Nd+Nu)} \text{ X } 100$$

Where, Nu = number of undamaged kernels, Nd = number of damaged kernels, U = weight of the undamaged kernels and D = weight of damaged kernels.

All the data pertaining generated in this investigation were statistically analysed using Fisher's method of analysis of variance in Completely Randomized Design (CRD). Significant and non-significant results of the variance due to treatments, was determined by calculating the respective 'F' values (Pansey and Sukhatme, 1985).

The standard error of the mean difference was calculated by using the following expression:

$$\text{S E M. } (\pm) = \sqrt{\frac{2 \text{ X Error Mean Square}}{\text{Number of replication}}}$$

The Critical Difference (C.D) was calculated to find out the significant or non-significant of mean of differences of treatments amongst treatments by using the following formula,

Critical Difference (C.D) = S. E(d). (±) x t

Where, t = tabulated value of 't' at 5 per cent level of probability for appropriate degrees of freedom.

3. Results and discussion

The results pertaining to the efficacy on mortality, adult emergence or insect survival, grain damage and weight loss were recorded as follows:

3.1 Mortality of adult weevils

The botanical powders were very less effective @1g dose: mortality recorded only on 24DAT in case of grains treated with powders of melia, lantana and papaya (Table 1).

At 3g/100g dose, mortality of weevils was recorded for melia, lantana, papaya and goatweed at 3 DAT, with 10.00, 13.33 and 26.67 per cent mortality, respectively. Highest mortality was recorded for lantana treated grains followed by melia and papaya treated grains with 76.66, 56.67 and 53.33 per cent, respectively (Table 2)

Among different treatments at 5g/100g grains mortality of 13.33 % was recorded in melia leaf powder treated grains at 1 DAT. Cent per cent mortality was recorded in malathion treated maize grains at 1 DAT. However, there was no mortality recorded in other treatments. At 3 DAT, highest cumulative mortality was recorded in treatment with melia leaf powder (36.67 %). Mortality in nishinda leaf powder treated grains was 26.67 %, which was at par with papaya and ageratum leaf powder treatment (16.67 %). At 7 DAT, cumulative adult mortality in melia and nishinda were statistically at par with each other with cumulative mortality of 56.67 % and 46.67 %, respectively. Cumulative adult mortality in lantana and papaya treated grains were statistically at par with each other, with cumulative mortality of 26.67 % and 36.67 %, respectively. The adult cumulative mortality in eupatorium, tulsi and ageratum was 23.33 %, 16.67 % and 23.33 %, respectively. At 14 DAT, highest cumulative mortality of 93.33 % was observed in melia treated grains followed by lantana treated grains (80.00 %). Cumulative mortality in nishinda and papaya leaf powder grains were statistically at par with each other with total mortality of 73.33% and 66.67%, respectively. Datura treated grains had cumulative mortality of 46.67 %. The mortality in eupatorium, tulsi and ageratum treatments was absent on 14 DAT. The overall effect of different plant leaf powders on mortality of adult *S. zeamais* showed that per cent cumulative mortality ranged from 23.33 % to 100 % after 24 days after treatment (DAT). Lantana offered cent per cent mortality followed by melia (Table 3). Thus, lantana and melia were highly effective in producing mortality in adults. Lowest cumulative mortality was observed in treatment with tulsi leaf powder (Table 1).

Similar findings were also reported by Ogendo *et al.* (2003), who observed 82.7-90.0 % mortality of *S. zeamais* after 21 DAT. Mixing of powdered leaves of *L. camara* with maize grains (in jute bags) @ 50g/2.5kg of grain, were found to be effective against *S. zeamais* but at the same time lower dosage of the powder had proven to be ineffective (Koona and Njoya 2004). Nishinda (*Vitex negundo*) has been widely known for its pesticidal properties. In this study it was found that when maize grains were treated with nishinda leaf powder @ 5g/100g grains, it caused 73.33 % mortality of *S. zeamais* at 24 DAT. These results are in congruent with those of Mishra *et al.* (1992), where they found that nishinda leaf powder @ 5 % caused 80 % mortality of *S. oryzae* on wheat seeds at 30 days after treatment. Similar finding were also reported in rice weevil on maize grain (Yevoor 2003). Govindan and Nelson (2010) also reported that nishinda @ 2 % caused 99.1 % mortality of rice weevil, *Sitophilus oryzae* L. infesting paddy grains within ten days of treatment. The cumulative mortality caused by Datura was 63.33 % at 24 DAT. More than 90 % mortality of adult *Z. Subfasciatus* was also observed for bean seeds treated with *J. curcas*, *D. Stramonium* and *P. Dodecondra* 96 hour after treatment at the rate of 15g/150g of grain application. Up to 66.67 % mortality was recorded in papaya leaf powder treated grains at 14 DAT. Mulungu *et al.* (2007) supports the present findings where they reported papaya leaf powder was the most effective in reducing the number of live insects against the infestation of maize weevil, *S. zeamais* (M.) on stored maize grains. Eupatorium was found to be less effective against *S. zeamais*, as it showed low adult cumulative mortality of 23.33 % at 7 DAT. However, in contrast eupatorium was reported to be very effective against rice weevil where it caused 66.6 % adult mortality (Yankanchi and Gadache 2010). The adult cumulative mortality in tulsi leaf powder treated grains @ 5g/100g grains was found to be very less *i.e.*, 16.67 % at 24 DAT. The studies conducted by Bekele *et al.* (1996) also reported that *O. sauve* in its dried or ground leaves form were not toxic to *S. zeamais.* Thus, it suggest that active ingredient in the plant product is more effective in liquid form. The present findings are almost similar with the findings of Parugrug and Roxas (2008) who reported that corn grains treated with powdered leaves of basil exhibited a low mortality of 0.66 % at 24 days after inoculation of insects, respectively.When maize grains were treated with *Ageratum conyzoides*, it showed low mortality of 23.33 % at 5 per cent. However, Moreira *et al.* (2007) found that hexane extract of ageratum was effective against coleopteran pests of stored products such as *Oryzaephilus surinamensis* L., *Rhyzopertha dominica* F. and *Sitophilus zeamais* M.

There are many reasons for the mortality of insects due to plant products. The plant powders can reduce insect movement which resulted into the death through dessication or occlusion of their spiracles, preventing respiration via tracheae (Koona and Njoya 2004). The use of plant powders could have resulted in higher death of insects as a result of physical barriers effect of the plant materials. This is because the powder could block the spiracles of the insects' thus impairing respiration leading to the death of insects. While feeding on whole grains, *S. zeamais* picks up lethal doses of the treatment thus resulting in stomach poisoning as reported by Mulungu *et al.* (2007). Lantazio *et al.* (1997) reported that mortality of insects by *L. camara* could be ascribed to high flavinoids contents, which was a reason for deterrence against insects. Such deterrence of plant powders could be due to the diffusing of persistent odours capable of suffocating the weevils in storage.

3.2 Number of adults emerged

In the present investigation, the maximum adult emergence was observed in maize grains treated with eupatorium leaf powder @ 5g/100g grains which did not differ significantly from datura and tulsi treated grains. The lowest number (1.33) was recorded in grains treated with lantana leaf powder. The number of adults emerged reduced effectively in grains treated with neem (1.67), lantana (1.33) and nishinda (1.66) which were statistically at par with each other. All the treatments significantly reduced the number of adult emergence as compared to the control (21.67) (Fig. 1). These findings are in agreement with the findings of Ogendo *et al.* (2003) who reported that the plant powders reduced F_1 adult insects by more than 75 % compared to the untreated control.The semio-chemical natures of botanical powders play an important role in altering the behaviour and physiology of the insects which adversely affects the egg laying and F_1emergence.

3.3 Per cent grain damage

The efficacy of different leaf powders were also tested for its potential to prevent the grain damage caused by *Sitophilus zeamais.* The results revealed that the minimum grain damage of 4.40 % was recorded in maize grains treated with lantana leaf powder. It was statistically at par with melia treated grains having per cent grain damage of 5.27 % respectively. The highest per cent grain damage was observed in maize grains treated with tulsi leaf powder (16.96 %) and it was at par with maize grains treated with datura, eupatorium and ageratum respectively. In nishinda and papaya treated grains the damage was 9.07 % and 8.46 %, respectively (Fig. 2).

Binggeli (1999), suggested that grounded powder of *L. camara* and other *Lantana* spp. acted as a repellent, mixed with the produce (i.e. grains) or placed in between the produce as protective layers (Sandwich method) and which can protect grain legumes from bruchids and potato tuber moth (*Phthorimaea operculella*) for about 6 months. Parugrug and Roxas (2008) also reported that powdered leaves of lantana were noted to be highly repellant which could be the cause of less damage to grains. Parveen Aziz (1988) reported that 5-10g (2.5-5 %) dried leaf powder of neem/bakain provided protection to maize grains against fungi and most of the insects up to three months. These powders have antifeedant properties thereby preventing feeding by the insects and reducing the grain damage. Similar results were also reported by Sunilkumar *et al.* (2005) who observed that there was 7 to 18 % seed damage in sorghum seeds treated with nishinda (*V. negundo)* @ 1 per cent from 30 to 90 days after treatment. Bekele *et al.* (1996) applied tulsi as dried or ground leaves, but it was not toxic to *S. zeamais* but at the same time its oil extracts were highly toxic to the weevil. Therefore, it suggests that tulsi leaves as powder was not effective in reducing the damage done by the weevils to the maize grains**.**

3.4 Per cent weight loss

The studies on efficacy of different plant powders to check the losses caused by *S. zeamais* revealed that the minimum weight loss of 0.87 % was recorded in lantana leaf powder treated grains and maximum loss in tulsi (6.19 %) treated grains which was statistically at par with eupatorium treated grains (5.70 %). In melia, nishinda and papaya weight loss were 1.21 %, 2.74 % and 1.95 %, respectively. Per cent weight loss in datura and ageratum treatments did not differ significantly from each other with weight losses of 3.14 %, and 3.44 %, respectively. These results indicate that lantana powder was most effective in reducing the loss followed by melia and papaya leaf powder. However, all the treatments significantly reduced weight loss as compared to control which had a weight loss of 12.42 %, respectively (Fig. 3).

Binggeli (1999), cited that ground plants of *L. camara* and other *L. camara* spp. when mixed with the produce or placed in between the produce as protective layers (Sandwich method) can protect grain legumes against bruchids and potato tuber moth (*Phthorimaea operculella*) for about 6 months by acting as repellent. Powdered leaves of *L. camara* mixed with 2.5 kg of maize grains contained in jute bags at the rate of 50 g were found effective against *S. zeamais*. However, lower dosage of the powder had been reported to be non-effective (Koona and Njoya 2004).The reason for low weight loss may also be due to high mortality percentage in both lantana and melia treated grains and also due to repellent and antifeedant properties of the powders. Maximum mortality of 98.8 % was achieved to adult *S. zeamais* with neemazal at a concentration of 12 g/kg seed after 14 days of treatment and greatly reduced F1 progeny emergence (Nukenine *et al.*, 2011).Similar findings were obtained by (Lakshmi Soujanya *et al.*, 2012a) who reported that the leaf powders of *Vitex negundo* L., *Adathoda vasica* L., *Catharanthus roseus* L. and *L. camara* at 5 % w/w proved to be toxic against *S. oryzae* in stored maize. Similarly, they also found that application of acetonic extracts of

V. negundo, A. vasica, C. roseus at 1 and 2 % concentration induced contact toxicity to *S. cereallella* resulting in suppression of adult emergence, grain damage and grain weight loss in stored maize (Lakshmi Soujanya *et al.,* 2012b). Maize treated with *A. conyzoides* @ 2 % w/w stored in jute bags indicated highest mortality of *S. oryzae*, led to minimum grain weight loss and depressed progeny development at 40 and 80 days after introduction of weevils (Lakshmi Soujanya *et al.*, 2013).

4. Conclusion

It was found that the botanical powders were not so effective @1g/100g of seed. At 3g/100g dose, mortality of weevils were recorded for melia, lantana, papaya and goatweed at 3DAT. Highest mortality was recorded in lantana treated grains followed by melia and papaya treated grains. Amongst different plant powders, lantana powder proved to be most effective followed by melia leaf powder @ 5g/100g grain. Highest adult cumulative mortality was observed in grains treated with lantana powder and the least mortality was obtained in tulsi treated grains. The lowest grain damage was recorded in maize grains treated with lantana leaf powder treatment. The minimum weight loss was recorded in lantana leaf powder treated grains and maximum loss in tulsi treated grains respectively. Hence, the present study concluded that lantana and melia leaf powder may be recommended as grain protectant for organic management system.

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Table 1. Effectiveness of different indigenous leaf powders @1g against maize weevil, *S. zeamais* (M.)

Treatments @ 1g/100g	**Adult cumulative mortality (%)**					
	1 DBT	1 DAT	3 DAT	7 DAT	14 DAT	24 DAT
Neem	0.00	0.00	0.00	0.00	0.00	23.33[d]
Lantana	0.00	0.00	0.00	0.00	0.00	13.33[d]
Nishinda	0.00	0.00	0.00	0.00	0.00	0.00
Datura	0.00	0.00	0.00	0.00	0.00	0.00
Papaya	0.00	0.00	0.00	0.00	0.00	16.67[b]
Eupatorium	0.00	0.00	0.00	0.00	0.00	0.00
Tulsi	0.00	0.00	0.00	0.00	0.00	0.00
Goatweed	0.00	0.00	0.00	0.00	0.00	0.00
Malathion	0.00	100[a]	100.00[a]	100.00[a]	100.00[a]	100.00[a]
Control	0.00	0.00	0.00	0.00	0.00	0.00
SEM(±)	-	-	--	--	--	2.58
CD at 5% ($P < 0.05$)	-	-	--	--	--	7.61

NB: Means followed by a common letter are not significantly different at 5% level

Table 2. Effectiveness of different indigenous leaf powders @3g against maize weevil, *S. zeamas* (M.)

Treatments @ 3g/100g	Adult cumulative mortality (%)					
	1 DBT	1 DAT	3 DAT	7 DAT	14 DAT	24 DAT
Neem	0.00	0.00	10.00	30.00	56.67	56.67
Lantana	0.00	0.00	13.33	40.00	76.66	76.66
Nishinda	0.00	0.00	0.00	0.00	10	36.67
Datura	0.00	0.00	0.00	0.00	6.67	33.33
Papaya	0.00	0.00	26.67	53.33	53.33	53.33
Eupatorium	0.00	0.00	0.00	0.00	0.00	0.00
Tulsi	0.00	0.00	0.00	0.00	0.00	0.00
Goatweed	0.00	0.00	10.00	10.00	10.00	10.00
Malathion	0.00	100	100.00	100.00	100.00	100.00
Control	0.00	0.00	0.00	0.00	0.00	0.00
SEM(±)	-	-	0.65	3.33	2.78	4.34
CD at 5% ($P < 0.05$)	-	-	1.91	9.83	8.22	12.82

NB: Means followed by a common letter are not significantly different at 5 % level

Table 3. Effectiveness of different indigenous leaf powders@ 5g against maize weevil, *S. zeamais* (M.)

Treatments @ 5g/100g	Adult cumulative mortality (%)					
	1 DBT	1 DAT	3 DAT	7 DAT	14 DAT	24 DAT
Neem	0.00	13.33^{b}	36.6^{b}	56.67^{b}	93.33^{ab}	93.33^{a}
Lantana	0.00	0.00	6.67^{d}	26.67^{cd}	80^{bc}	100.00^{a}
Nishinda	0.00	0.00	26.67^{bc}	46.6^{bc}	73.33^{c}	73.33^{b}
Datura	0.00	0.00	0.00	6.67^{e}	46.67^{d}	63.33^{b}
Papaya	0.00	0.00	16.67^{cd}	36.67^{c}	66.67^{c}	66.67^{b}
Eupatorium	0.00	0.00	10.00^{d}	23.33^{d}	23.33^{e}	23.33^{c}
Tulsi	0.00	0.00	6.67^{d}	16.67^{de}	16.67^{e}	16.67^{c}
Goatweed	0.00	0.00	16.67^{cd}	23.33^{d}	23.33^{e}	23.33
Malathion	0.00	100^{a}	100.00^{a}	100.00^{a}	100.00^{a}	100.00^{a}
Control	0.00	0.00	0.00	0.00	0.00	0.00
SEM(±)	-	-	2.79	4.08	4.34	4.34
CD at 5% ($P < 0.05$)	-	-	8.22	12.04	12.82	12.82

NB: Means followed by a common letter are not significantly different at 5 % level

Figure 1. Bioefficacy of different botanical powders on numbers of adult emerged @1g, 3g and 5g

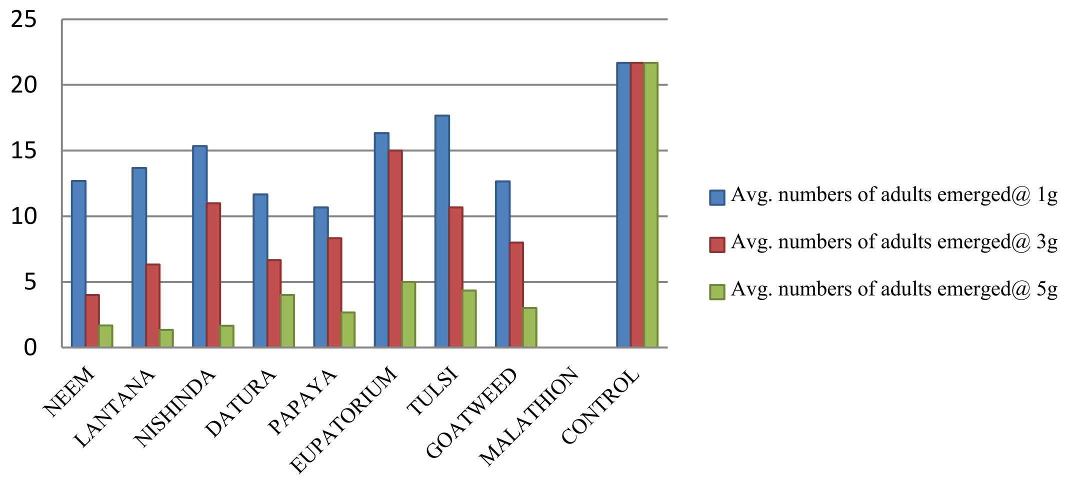


Figure 2. Bioefficacy of different botanical powders on grain damage (%) @1g, 3g and 5g

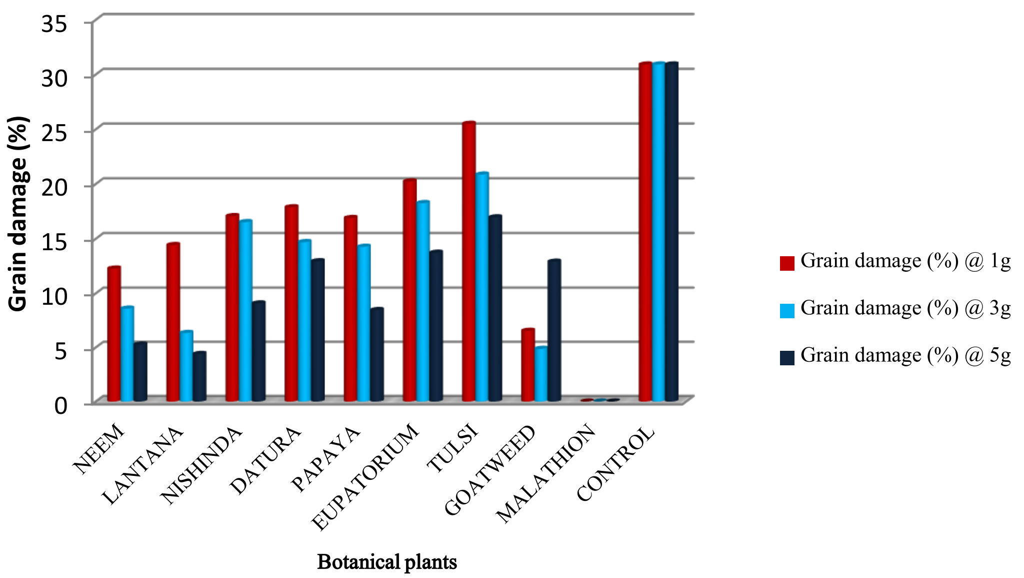
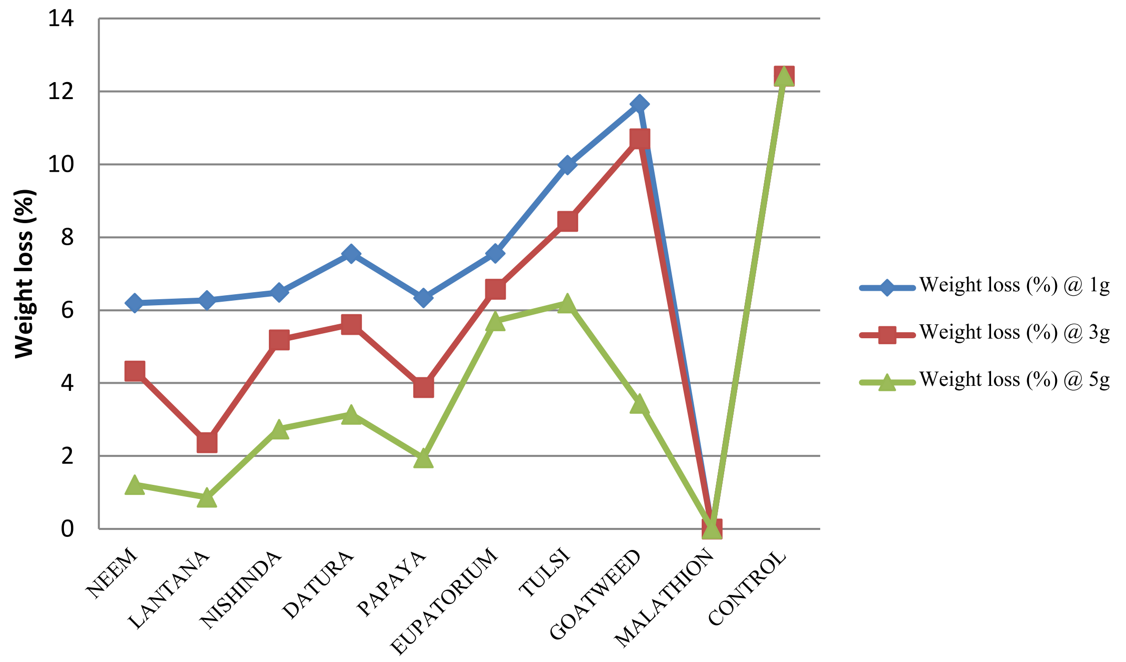


Figure 3. Bioefficacy of different botanical powders on weight loss(%) @1g, 3g and 5g



6. References

Adams JM (1976) Weight loss caused by development of *S. zeamais* in maize. Journal of stored Product Research 12: 269-72

Arthur FH (1996) Grain protectants: current status and prospects for the future. Journal of stored Product Research 32:293–302

Basyal K, Sapkota R, Bajryacharya ASR, and SS Bhattarai (2022) Use of botanicals for management of weevil (*Sitophilus zeamais* Motschulky) in maize storage. The Journal of Agriculture and Environment 23:166-176

Bekele AJ, Obeng Ofori D, and A Hassanali (1996) Evaluation of *Ocimum suave* (Willd) as a source of repellents, toxicants and protectants in storage against three stored product insect pests. International Journal of Pest Management 42(2):139-42

Bhuiyah MIM and Quiniones AC (1990) Use of leaves of lagundi, *Vitex negundo* L. as corn seed protectants against the corn weevil, *Sitophilus zeamais* M. Bangladesh Journal of Zoology 18(1):127–29

Bhuiyah MIM, Islam N, Begum A, and MA Karim (1990) Biology of rice weevil *Sitophilus oryzae* Linnaeus. Bangladesh Journal of Zoology18:67-74.

Binggeli P (1999) *Lantana camara* L. (Verbenaceae). Plant Ecology

Carrieri F, Raimo F, and L Pentangelo (2013) *Fusarium proliferatum* and *Fusarium tricinctum* as causal agents of pink root of onion bulbs and the effect of soil solarization combined with compost amendment in controlling their infections in field. Crop Protection 43:31–37

Correa AS, Pereira EJG, Cordeiro EMG, Braga LS, and RNC Guedes (2011) Insecticide resistance, mixture potentiation and fitness in populations of the maize weevil (*Sitophilus zeamais*). Crop Protection 30: 1655–1666

Delima CPF (1987). Insect pests and post-harvest problems in the tropics. Insect Sci. Appl. 8:673-76

Garcia JR (1990) Bioassay of Five Botanical Materials Against the Bean Weevil, *Callosobruchus chinensis* (L.) on Mungbean (*Vigna radiata* L.), Unpublished master's thesis. University of the Philippines at Los Baños, College, Laguna.

Giga DP and Smith RH (1985) Ovipositional markers *in Callosobruchus maculates* (F.) and C. rhodestanus (PIO) (Coleoptera:Bruchidae). Rizet Riziculture et vivrieres Tropicals 8:167-84

Girish GK, Goyal RK, and Krishnamuarthy K (1985) Steps taken by the departments of foods for minimising post-harvest food losses at farm level. Bulletin of Grain Technology 23: 168-81

Grenier AM, Pintareau B, and P Nardo (1994) Enzymatic variability in three species of *Sitophilus* (Coleoptera: Curculionidae). Journal of Stored Product Research30: 201-13

GuzzoEC, Tavares MAGC, and Vendramim JD (2006) Evaluation of insecticidal activity of aqueous extracts of *Chenopodium* spp. in relation to *Rhyzopertha dominica* (Fabr.) (Coleoptera: Bostrichidae), pp. 926–930. In: Proceedings of the 9th International Working Conference on Stored-Product Protection, 15–18 October 2006, Campinas, Sao Paulo, Brazil. Brazilian Post-harvest Association- ABRAPOS, Passo Fundo

Hakeem SA, Wani RA, Alie BA, Ansarul Haq S, Seerat-u-Nissa, Bashir S, Bahar FA, Tanveer-ul-Hassan, Baba AY, Lone AA, and FA Nehvi (2017) Management of Maize Weevil (*Sitophilus zeamais*) Using Different Grain Protectants. International Journal of Current Microbiology and Applied Science 6(8): 2520-2523

Haque MA, Nakakita H, Ikenaga, and N Sota (2000). Development inhibiting activity of some tropical plants against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Journal of Stored Product Research 36: 281–287

Hill, DS (2002) Pests of stored food stuffs and their control. Kluwer Academic Publ, Boston, pp 55–63

Lakshmi Soujanya P, Sekhar JC, Kumar P, and SB Suby (2012a) Use of plant leaf powders to assess and manage *Sitophilus oryzae* (L.)(Coleoptera: curculionidae) in stored maize grain. Indian Journal of Plant Protection 40:1-4

Lakshmi Soujanya P, Sekhar JC, Kumar P, and SB Suby (2012b) Bioactivity of four plant extracts against Angoumois grain moth, *Sitotroga cerealella* (Oliv.) (Lepidoptera: Gelechidae) in stored maize grain. Maize Journal 1:79–81

Lakshmi Soujanya P, Sekhar JC, and P Kumar (2013) Insecticidal effects of plant extracts against *Sitophilus oryzae* L. (Coleoptera: curculionidae) in stored maize. In: Book of abstracts. International conference on Insect Science, GKVK, Bangalore, p 13

Lantazio V, Cardinali A, Linsalata V, Perrino P, and NO Ng (1997) Flavinoid hplc Fingerprints OF Wild Vigna species. In: Advances in cowpea Research, (Eds.) Singh, B.B., Mohan Raj, D. R., Dashiell, K. E. and Jackai, L.E.N. Copublication of International Institute of Tropical Ariculture (IITA) and Japan International Research Centre for Agricultural Sciences (JIRCAS). IITA, Ibadan, Nigeria.Pp :66-74

Lee S, Peterson CJ, and JR Coats (2003) Fumigation toxicity of monoterpenoids to several stored product insects. Journal of Stored Product Research 39:77–85

Magan N, Hope R., Cairns V, and Aldred D (2003) Post harvest fungal ecology: impact of fungal growth and mycotoxin accumulation in stored grain. European Journal of Plant Pathology109:723–730

Mohan S, Pretheep KP, and P Balasubramaniam (2010) Insecticide resistance- stored-product Insects. LAP Lambert Academic Publ

Mulungu LS, Lupenza G, Rieuben SOW, Misangu RW (2007). Evaluation of botanical products as Stored grain protectant against maize weevil *S. zeamais*. Journal of Entomology 4:258–262

Nukenineb EN, Tofel HK, and C Adler (2011) Comparative efficacy of neemazal and local botanicals derieved from *Azadirachta indica* and *Plectranthus glandulosus* against *Sitophilus zeamais* on maize. Journal of Pest Science 84:479–486

Ogendo JO, Belmain SR, Deng AL, and DJ Walker (2003) Comparison of Toxic and Repellent Effects of *Lantana Camara* L. with *Tephrosia vogelii* Hook and a Synthetic Pesticide Against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in Stored Maize Grain. Insect Science and Its Application 23(2): 127-35

Pansey VG and Sukhamte PV (1985) Statistical Methods for Agricultural Workers, ICAR, New Delhi

Parugrug ML, and AC Roxas (2008) Insecticidal action of five plants against maize weevil, *Sitophilus zeamais* Motsch. (coleoptera: curculionidae). Science Technology Journal 8 (1)

Parveen Aziz (1988) Effect of Neem/Bekain leave and bark powder on the storage of maize and gram. Pakistan Journal of Agricultural Research 9(4):483-487

Raja N, Albert S, Babu A, Ignacimuthu S, and Dorn S (2001) Role of botanical protectants and larval parasitoid *Dinarmus vagabundus* (Timberlake) (Hymenoptera: Pteromalidae) against *Callosobruchus maculatus* Fab. (Coleoptera: Bruchidae) infesting cowpea seeds. Malaysian Applied Biology 29(1–2):55–60

Reddy UK and Pushpamma P (1980) Effect of insect infestation and storage on the nutritional quality of different varieties of pigeon pea. In Proc. Int. Workshop on pigeon pea, ICRISAT, Patancheru, Andhra Pradesh, India. Pp: 451-53

Sclar CD (1994) Neem: Mode of Action of Compounds Present in Extracts and formulations of Azadirachta indica Seeds and their efficacy to Pests of Ornamental Plants and to Non-target Species.

Shiberu T, and Negeri M (2017) Determination of the Appropriate Doses of Promising Botanical Powders against Maize Weevil, *Sitophilus zeamais* Motsch. (Coleoptera: *Curculionidae*) on Maize Grain. Agriculture Research and TechnologyVolume 6 (5)

Singal V (1999) Food Grains. Indian Agriculture Pg: 99-104

Subramanyam B and Hagstrum DW (1995) Resistant measurement and management. In: Subramanyam B, Hagstrum DW (eds) Integrated management of insects in stored products. Marcel Dekker, New York, pp 331–397

Sunilkumar, Naganagoud A, and BV Patil (2005) Evaluation of botanicals powders against rice weevil (*Sitophilus oryzae*) in stored sorghum. Karnataka Journal of Agriculture Science 18(4):1117-1120.

Tapondjou LA, Adler C, Bouda H, and DA Fontem (2000) 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 38(4):395–402

Tiwari S, Thapa RB, and S Sharma (2018) Use of botanicals for weevil management: a integrated approach of maize weevil (*sitophilus zeamais*) management in a storage condition*J.* Inst. Agric. Anim. Science 35: 167-172 (2018)

YankanchiSR and Gadache AH (2010) Grain protectant efficacy of certain plant extracts against rice weevil, *Sitophilus oryzae* L. (Coleoptera: Curculionidae). Journal of Biopesticides.3(2): 511 - 13

Yevoor (2003). Biology and management of rice weevil, *Sitophilus oryzae* (Linn.) in maize grains.*M. Sc. (Agri.) Thesis*, Univ. of Agri. Sciences, Dharwad.