

## Research Article

# Evaluation of Locally Available Botanicals for the Management of Maize Weevil (*Sitophilus zeamais* Motsch.) in Room Storage Condition

Bishnu Prasad Neupane <sup>1</sup>, Prem Nidhi Sharma,<sup>1</sup> Sunil Aryal,<sup>2</sup> and Jiban Shrestha <sup>3</sup>

<sup>1</sup>Nepal Agricultural Research Council, National Entomology Research Centre, Khumaltar, Lalitpur, Nepal

<sup>2</sup>Nepal Agricultural Research Council, Horticulture Research Station, Malepatan, Kaski, Nepal

<sup>3</sup>Nepal Agricultural Research Council, National Plant Breeding and Genetics Research Centre, Khumaltar, Lalitpur, Nepal

Correspondence should be addressed to Bishnu Prasad Neupane; bisnu\_neupane2000@yahoo.com

Received 27 May 2022; Accepted 28 September 2022; Published 26 October 2022

Academic Editor: In Sik Chung

Copyright © 2022 Bishnu Prasad Neupane et al. This is an open access article distributed under the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original work is properly cited.

From April to July 2019, an experiment was conducted in Khumaltar, Lalitpur (27°39.312'N, 85° 19.586'E, and 1322 m above sea level) to assess the effectiveness of plant materials on maize weevil (*Sitophilus zeamais* Motsch.) control under laboratory conditions (maintained room temperature of  $28.5 \pm 2^\circ\text{C}$ , and relative humidity of  $72 \pm 5\%$ ) treatments were *Acorus calamus* (rhizome powder) @  $5 \text{ g}\cdot\text{kg}^{-1}$ , *Melia azadirach* (rhizome powder) seed @  $5 \text{ g}\cdot\text{kg}^{-1}$ , *Curcuma domestica* (rhizome powder) @  $5 \text{ g}\cdot\text{kg}^{-1}$ , mustard oil @  $2 \text{ mL}\cdot\text{kg}^{-1}$ , *Gingiber officinalis* (rhizome powder) @  $5 \text{ g}\cdot\text{kg}^{-1}$ , rice husk ash @  $5 \text{ g}\cdot\text{kg}^{-1}$ , and an untreated control. These treatments were evaluated in a completely randomized design (CRD) with three replications. At four months, the grains treated with *Acorus calamus* had the least weight loss (6.66%), and grain damage (1.23%). Grain damage (18%), and weight loss (62.33%) were the highest in the control treatment. Similarly, grains treated with *Acorus calamus* had the fewest number of exit holes (3.10 per 100 g of maize seed), while the control treatment had the largest number of exit holes (45.10 per 100 g of maize seed). There was a significantly higher number of weevils in the control treatment (55.80 per 250 g maize grains), but only a few numbers of weevils in the *Acorus calamus*-treated grains (2.50 per 250 g maize grains). In contrast with other plant materials treated grains, the maize weevil showed a reduced preference for *Acorus calamus*- treated grains with low weight loss, and grain damage. These findings can be used to promote locally accessible botanicals for maize weevil control in Nepal.

## 1. Introduction

In Nepal, maize is the second most important cereal crop after rice in terms of area (957,650 ha), and productivity ( $2.96 \text{ Mt}\cdot\text{ha}^{-1}$ ) [1]. Both in the field and the storehouse, this crop is vulnerable to a wide variety of insect pests. A few insects such as *Sitophilus zeamais* (Motsch.), and *Sitophilus oryzae* (L.) have been found infesting maize. *Rhizopertha dominica* (Fabricius), *Tribolium castaneum* (Herbst), *Corcyra cephalonica* (Stainton), and *Sitotroga cerealella* (Oliver) are also reported to attack maize [2]. The maize weevil (*Sitophilus zeamais* Motsch.) is the most common pest of maize in Nepal [3]. This is a coleopteron insect that feeds on the kernel starch of harvested corn, causing quality,

and weight loss [4]. *Sitophilus zeamais* is believed to cause losses of 20–80% in tropical countries [5], but losses of 18–40% have been reported in the Chitwan region of Nepal [6].

Effective and environmentally safe insect control techniques are still lacking in Nepal in storehouses. Synthetic pesticides can be used to control insect pests in storage, but their repeated application leads to residues, detrimental effects on nontarget organisms, and health, and environmental issues [7]. Pest control with pesticides is usually costly for small-scale farmers and a time-consuming process [8]. Given the negative consequences of synthetic pesticides, plant insecticides, which are more biodegradable, less dangerous to humans, and safe for the environment, appear

to be a feasible option for controlling weevils [9]. Nepal is home to a wide variety of plant species that contribute to the biodiversity of the country. This plant material can protect stored grain from pests [10]. In fact, fifty plant species can be used to control insect pests on crops, and grains in Nepal [11]. For example, *Acorus calamus*, *Azadirachta indica* oil, *Melia azadirach* seed powder, *Zanthoxylum armatum*, and *Artitimesia vulgaris* are some of the remedies that can help reduce corn aphids [12]. These plant compounds have both lethal, and repellent properties but are not toxic to mammals [13]. The aim of this study was to evaluate the efficacy of various botanicals for protecting maize from corn weevil damage in warehouses.

## 2. Materials and Methods

**2.1. Experimental Site and Lab Condition.** The study was carried out in the laboratory of the National Entomology Research Centre in Khumaltar, Lalitpur, Nepal. It is located at an altitude of 1322 meters above sea level, at 27°39.312' north latitude, and 85°19.586' east longitude. The temperature, and humidity of the study room were maintained using a heater, and recorded daily with the help of a digital thermo hygrometer at 6:00 AM, 12:00 PM, and 6:00 PM during the experimental period. The average temperature, and relative humidity at the warehouse were  $28.5 \pm 2^\circ\text{C}$  and  $72 \pm 5\%$ , respectively, during the study period.

**2.2. Selection of Plant Materials.** Fresh seeds of *Melia azadirach*, rhizome of *Curcuma domestica*, *Zingiber officinalis*, and *Acorus calamus* were collected from Chitwan, Kavrepalanchowk, and Lalitpur, Nepal, and kept for two months in the shade for drying, and crushed into powder by hand with a mortar, and pestle. The prepared powder remained safe for use in research trials. Fresh mustard oil was collected from oil mills. The mustard oil was stored in a refrigerator held at  $4^\circ\text{C}$  until it was used in the experiment. Ash was made by burning rice husks and collecting them in polyethylene bags after being sifted. The maize variety Manakamana-3 was collected from farmers' fields of Bhakundebes, Kavrepalanchowk, and used for the experiment. The grain of this maize variety was harvested after five months of planting. At the time of harvesting, the approximate value of the grain moisture content was 15%, and the ambient temperature was  $20^\circ\text{C}$ . The grain moisture level was measured by a Willy Dividable Moisture Meter. The grain collected from different farmers' fields was cleaned, and dried in the sun. The moisture level was maintained at 14%. The grain was stored under a semi-airtight condition in SuperGrain IV-R™ bags (74 cm wide and 64 cm long) of 25 kg holding capacity (supplied by GrainPro Inc.), and open-weave polypropylene bags of the same capacity. The open ends of the SuperGrain IV-R™ bags were cut to fit the height dimension of these polypropylene outer bags. The SuperGrain IV-R™ bags were kept without tightening their open ends (without proper sealing) in order to keep them in semi-airtight condition. The airtightness of the bag can be affected by improper sealing of the end of the bag, and perforations in the plastic cover.

Grain yield ( $\text{kg}\cdot\text{ha}^{-1}$ ) at 14% moisture content was calculated using fresh ear weight.

$$\text{Grain yield (kg/ha)} = \frac{\text{F.W. (kg/plot)} \times (100 - \text{HMP}) \times S \times 10000}{(100 - \text{DMP}) \times \text{NPA}}, \quad (1)$$

where F.W. = fresh weight of ear in kg per plot at harvest, HMP = grain moisture percentage at harvest, DMP = desired moisture percentage, i.e., 14%; NPA = net harvest plot area,  $\text{m}^2$ , and S = shelling coefficient, i.e., 0.8.

This plot yield ( $\text{kg}\cdot\text{ha}^{-1}$ ) was then expanded to grain yield ( $\text{t}\cdot\text{ha}^{-1}$ ).

**2.3. Experimental Design and Treatment Details.** The experiment was carried out from April 1 to July 30, 2019, at the laboratory of the National Entomology Research Centre, Khumaltar, Nepal. Six kg of corn seeds var. Manakamana-3 were used for each treatment, and were kept under a semiairtight condition in SuperGrain IV-R™ bag. An untreated control, and six different botanical treatments including *Acorus calamus* (rhizome powder) @  $5\text{ g}\cdot\text{kg}^{-1}$ , *Melia azadirach* (seed powder) @  $5\text{ g}\cdot\text{kg}^{-1}$ , *Curcuma domestica* (rhizome powder) @  $5\text{ g}\cdot\text{kg}^{-1}$ , mustard oil @  $2\text{ mL}\cdot\text{kg}^{-1}$ , *Gingiber officinalis* (rhizome powder) @  $5\text{ g}\cdot\text{kg}^{-1}$ , and rice husk ash @  $5\text{ g}\cdot\text{kg}^{-1}$  comprised the study. The experiment was organized in a completely randomized design (CRD) with three replications (two kg each), and twenty-one experimental units.

**2.4. Data Collection and Observations.** Data was collected before, and at specific intervals i.e., 60 days, 90 days, and 120 days after setting up the experiment. Using a sampler (Double-tube sampling spear), a 250 g random sample of maize was taken from each experimental unit, and analyzed. The grain damage percentage was calculated with the following formula [15]

$$\text{Grain damage (\%)} = \frac{(\text{Number of damaged grains})}{(\text{Total number of grains})} \times 100. \quad (2)$$

For estimating adult emergence number of live, and dead insects that emerged from randomly taken 100-gram seed samples of each experimental unit were counted.

Weight loss due to insects is calculated by subtracting from the dry weight of grain before the insect feeding to the dry weight of grain after feeding the insect.

**2.5. Statistical Analysis.** Using GenStat version 18, all data were analyzed using a one-way ANOVA. The Duncan multiple range test (DMRT) was used to compare means which were separated by the least significance difference (LSD) at  $P < 0.05$  [16].

## 3. Results and Discussion

For the management of maize weevil in storehouses, laboratory tests were conducted to identify ideal botanicals that proved to be superior to synthetic chemicals. The findings

TABLE 1: Effects of different botanicals on weevil population in maize seeds.

Botanicals	Weevil population per 250 g maize seed		
	At 60 days	At 90 day	At 120 days
<i>Gingiber officinalis</i> (rhizome powder) 5 g.kg <sup>-1</sup>	1.06a	1.34b	55.10b
<i>Curcuma domestica</i> (rhizome powder) 5g.kg <sup>-1</sup>	1.14a	1.27ab	47.10b
Mustard oil 2 mL.kg <sup>-1</sup>	0.97a	0.85a	19.50a
Rice husk ash 5 g.kg <sup>-1</sup>	1.15a	1.98 b	28.10ab
<i>Melia azadirach</i> (seed powder) 5 g.kg <sup>-1</sup>	1.18a	0.68a	6.21a
<i>Acorus calamus</i> (rhizome powder) 5 g.kg <sup>-1</sup>	0.68a	0.51a	2.5a
Control	2.33b	2.91c	55.80b
P Value	0.012	< 0.001	0.008
CV (%)	21.3	15.9	29.7
LSD (0.05)	0.751	0.824	29.76

Means within the column with the same letter are not significantly different at the 0.05 probability level, CV: coefficient of variation, LSD: least significant difference, and SEM: standard error of the mean.

TABLE 2: Effect of different botanicals on exit hole numbers caused by maize weevil (*Sitophilus zeamais* Motsch.) in maize seeds.

Botanicals	No of exit holes per 100 g maize seed		
	At 60 days	At 90 day	At 120 days
<i>Gingiber officinalis</i> (Rhizome powder) 5 g.kg <sup>-1</sup>	1.57a	6.47b	35.80b
<i>Curcuma domestica</i> (rhizome powder) 5 g.kg <sup>-1</sup>	1.36a	5.13b	31.80b
Mustard oil 2 mL.kg <sup>-1</sup>	1.52a	3.47a	17.80a
Rice husk ash 5 g.kg <sup>-1</sup>	1.37a	3.13a	23.50b
<i>Melia azadirach</i> (seed powder) 5 g.kg <sup>-1</sup>	1.26a	2.80a	12.50a
<i>Acorus calamus</i> (rhizome powder) 5 g.kg <sup>-1</sup>	0.68a	1.80a	3.10a
Control	2.33b	11.80c	45.10c
P Value	0.017	0.001	0.002
CV (%)	11.3	12.8	23.6
LSD (0.05)	0.747	2.663	17.91

Means within the column with the same letter are not significantly different at the 0.05 probability level, CV: coefficient of variation, LSD: least significant difference, and SEM: standard error of the mean.

were analyzed and discussed, and evidence from previous studies was used to support them.

**3.1. Weevil Population.** Maize seeds treated with *Acorus calamus* (rhizome powder) and *Melia azadirach* (seed powder) had a significantly better effect on the weevil population control compared to other treatments ( $P < 0.05$ ). The lowest number of weevils was found in seeds treated with *Acorus calamus* (2.5), followed by seeds treated with *Melia azadirach* (6.21), mustard oil (19.50), and rice husk ash (28.10), while the highest was found (55.80) in the control (Table 1) at 120 days after treatment.

Paneru et al. [17] reported that the concentrations of B-asarone in *calamus* rhizome powder were 6.4%, and 4.7% (mature parts of rhizomes harvested in the highlands, and lowlands, respectively), 3%, 6%, and 4.0. v/v (ripe part of rhizomes harvested in high, and low altitudes, respectively) (young part of rhizomes harvested in high and low altitudes, respectively). By preventing the removal of the exoskeleton during larval development, active phytochemicals such as alkaloids have been reported to inhibit growth, and limit larval survival [18]. Other compounds such as isoflavonoids, flavonoids, and terpenoids have been observed to inhibit insect reproduction, and population growth [19, 20].

**3.2. Number of Exit Holes per 100 Gram of Maize.** The effect of different botanical treatments also had a significant effect ( $P < 0.05$ ) on the number of exit holes made by the weevil. At the end of the experiment, exit holes opened by the weevil were the highest in the control (45.10), and lowest in the seeds treated with *Acorus calamus* (3.10) (Table 2). The result of a small number of adult emergence studies clearly demonstrated the superior performance of *Acorus calamus* rhizome powder at 5 g.kg<sup>-1</sup> seeds to preserve maize seeds for four months. A few eggs laid on *Acorus calamus* rhizome powder @ 5 g.kg<sup>-1</sup> seeds did not complete their development resulting in a reduced number of adult emergencies, and registered breeding holes, which may also be due to low egg hatchability. Compared to other treatments such as neem, malabar nut, and wormwood-treated seeds, Panthee [21] suggested that *A. calamus*-treated maize seeds produced a lower weevil population, resulting in fewer exit holes [21]. A similar result was shown by Shrestha [22] who reported that negligible exit holes in maize kernels were noted in seeds treated with *Acorus calamus* (rhizome powder).

**3.3. Grain Damage.** All botanicals used for weevil control had a significant effect on grain damage compared to the control ( $P < 0.05$ ). The percentage of grain damage was the lowest in the *Acorus calamus* (1.23%) and the highest in the

TABLE 3: Effect of different botanicals on grain damage by maize weevil (*Sitophilus zeamais* Motsch.) in maize seeds.

Botanicals	Grain damage (%)		
	At 60 days	At 90 days	At 120 days
<i>Gingiber officinalis</i> (rhizome powder) 5 g·kg <sup>-1</sup>	2.53a	3.36bc	16.88c
<i>Curcuma domestica</i> (rhizome powder) 5 g·kg <sup>-1</sup>	1.95a	3.77bc	13.64bc
Mustard oil 2 mL·kg <sup>-1</sup>	2.08a	3.23 b	12.48bc
Rice husk ash 5 g·kg <sup>-1</sup>	1.50a	3.57bc	13.56bc
<i>Melia azadirach</i> (seed powder) 5 g·kg <sup>-1</sup>	1.62a	2.60ab	7.62ab
<i>Acorus calamus</i> (rhizome powder) 5 g·kg <sup>-1</sup>	0.73a	0.63a	1.23a
Control	4.72b	5.40c	18.0c
P Value	0.026	0.013	0.002
CV (%)	20.1	12.5	16.8
LSD (0.05)	2.028	2.067	6.725

Means within the column with the same letter are not significantly different at the 0.05 probability level, CV: coefficient of variation, LSD: least significant difference, and SEM: standard error of the mean.

TABLE 4: Effects of different botanicals on weight loss by maize weevil (*Sitophilus zeamais* Motsch.) after 120 days in maize seeds.

Botanicals	Initial weight (kg)	Initial moisture (%)	Change in grain moisture (%)	Weight loss due to moisture (kg)	Dry weight before insect feeding (kg) (a)	Dry weight after feeding insect (kg) (b)	Weight loss due to weevil (kg) (a-b)
<i>Gingiber officinalis</i> (rhizome powder) 5 g·kg <sup>-1</sup>	6	14	13.33b	0.156c	5.84	5.12c	0.72b
<i>Curcuma domestica</i> (rhizome powder) 5 g·kg <sup>-1</sup>	6	14	40.33c	0.107 b	5.89	3.73b	2.16c
Mustard oil 2 mL·kg <sup>-1</sup>	6	14	11.67b	0.159c	5.84	5.22c	0.62ab
Rice husk ash 5 g·kg <sup>-1</sup>	6	14	40.00c	0.109 b	5.89	3.79 b	2.1c
<i>Melia azadirach</i> (seed powder) 5 g·kg <sup>-1</sup>	6	14	37.00c	0.113b	5.88	3.91b	1.97c
<i>Acorus calamus</i> (rhizome powder) 5 g·kg <sup>-1</sup>	6	14	6.67a	0.168c	5.83	5.47d	0.36a
Control	6	14	50.67d	0.089a	5.91	2.58a	3.33d

Means within the column with the same letter are not significantly different at the 0.05 probability level.

control (18.0%) after 120 days (Table 3). The present results were supported by the results of Kumar [23] who found that *Acorus calamus* rhizome powder gave the maximum seed protection of up to 60 Days After Silking at a rate of 1%. In the current study, seed damage was minimal even after 120 days. This result was supported by Reddy and Reddy [13]. According to Kudachi [24], seeds treated with *Acorus calamus* rhizome powder @ 1% were significantly better without damage to the seeds, but untreated control seeds suffered the most (82%). GC [25] also found that the *Acorus calamus* (50 g·kg<sup>-1</sup>) was the most effective, and least damaging plant against maize weevil over a nine-month period. This research is backed by Paneru and Thapa's [26] findings that *Acorus calamus* rhizome powder caused negligible grain damage during storage.

**3.4. Weight Loss.** The weight loss was adjusted for the loss of moisture for each treatment. The highest weight loss due to moisture loss (%) was observed in plant-derived cereals

compared to the control. Similarly, significant weight loss due to weevil was observed in plant-derived cereals compared to the control ( $P < 0.05$ ) (Table 4). The lowest loss due to weevil was observed in maize seeds treated with *Acorus calamus* (0.36 kg), while the highest loss was observed in the control (3.33 kg) at 120 DAS (Table 4). The highest loss in control was due to the consumption of grains by the weevil. These findings are supported by Paneru et al. [27], Jilani [28], Biradar [29], and Kumar [23] who found that *Acorus calamus* was a good preservative with a long-lasting effect on mung beans. Kalasagonda [30] confirmed these results by stating that the weight of wheat grain did not decrease at a concentration of 0.8%. *Acorus calamus* (30 g·kg<sup>-1</sup>) in corn grains caused the least damage, and at the same time, the least weight loss on the shallow and moderate sloping slopes of Nepal [31]. Accordingly, Regmi et al. [32] came to the same conclusion and reported that seeds treated with *Acorus calamus* lost little weight in a basement.

#### 4. Conclusion

Among several plant materials tested, *Acorus calamus* (rhizome powder @ 5g.kg<sup>-1</sup> maize seed) significantly reduced weight loss, amount of grain damage, number of holes, and weevil population. Thus, this finding helps to develop a storehouse based on the integrated pest management model that could represent an environmentally sound, economically viable, and socially acceptable approach in the rural area of Nepal.

#### Data Availability

Data will be made available upon request.

#### Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

#### Authors' Contributions

Bishnu Prasad Neupane conceived and designed the experiments, performed the experiments, analyzed, and interpreted the data, and wrote the paper. Prem Nidhi Sharma, and Sunil Aryal gave guidance, monitored the experiment, and reviewed the initial draft of the manuscript. Jiban Shrestha reviewed the initial draft of the manuscript, and contributed to the analysis of the data.

#### Acknowledgments

This research was supported by the fund of the National Entomology Research Centre, Khumaltar, Lalitpur, Nepal.

#### References

- [1] MOALD, *Statistical Information on Nepalese Agriculture 2019/020, the Government of Nepal, Ministry of Agriculture and Livestock Development, Planning and Development Co-operation Coordination Division, Statistics and Analysis Section*, Singha Durbar, Kathmandu, Nepal, 2020.
- [2] F. P. Neupane, S. M. Shrestha, R. B. Thapa, and T. B. Adhikari, *Crop Protection (Nepal)*, Institute of Agriculture and Animal Science, Rampur, Chitwan, Nepal, 1991.
- [3] I. Sherpa, N. G. Ojha, and A. R. Sharma, *Why Farmers Adopt or Reject Agricultural Technology: A Case Study of Improved Maize and Wheat Varieties in the Ex-Local Largest Area of Pakhribas*, Ag, PAC Technical Paper, Dhankuta, Nepal, 1997.
- [4] P. Trematerra, R. Ianiro, C. G. Athanassiou, and N. G. Kavallieratos, "Behavioural responses of *Sitophilus zeamais* Motschulsky adults to conditioned grain kernels," *Journal of Stored Products Research*, vol. 53, pp. 77–81, 2013.
- [5] P. L. Pingali and S. Pandey, *Meeting World Maize Needs: Technology Opportunities and priorities for the Publication Sector*, CIMMYT 1999-2000 World Maize Facts and Trends, 2001.
- [6] S. D. Sharma, R. B. Thapa, G. B. Kc, G. Bhandari, and S. Tiwari, "Studies on food preferences of maize weevil, *Sitophilus zeamais* Mots. to different crops in Chitwan, Nepal," *Journal of Maize Research and Development*, vol. 2, no. 1, pp. 58–65, 2016.
- [7] N. D. G. White and J. G. Leesch, *Chemical Control*, Marcel Dekker, New York, NY, USA, 1995.
- [8] B. N. Iloba and T. Ekrakene, "Comparative assessment of the insecticidal effect of *Azadirachta indica*, *Hyptis suaveolens* and *Ocimum gratissimum* on *Sitophilus zeamais* and *Callosobruchus maculatus*," *Journal of Biological Sciences*, vol. 6, no. 3, pp. 626–630, 2006.
- [9] E. C. Guzzo, M. A. G. C. Tavares, and J. D. Vendramim, "Evaluation of insecticidal activity of aqueous extracts of *Chenopodium* spp. in relation to *Rhizopertha dominica* (Fabr.) (Coleoptera: bostrichidae)," 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, AGRIS, Passo Fundo, Brazil, October, 2006.
- [10] F. P. Neupane, "Insect pest of crop pest and their integrated management," *Sajha Prakashan, Pulchowk, Lalitpur*, vol. 243, 2009.
- [11] B. K. Gyawali, "Integrated pest management through indigenous techniques in Nepal," *Indigenous Management of National Resource in Nepal*, HMGN/MoA, Winrock International, Kathmandu, Nepal, 1993.
- [12] R. B. Paneru, V. R. Duwadi, R. Khanal, and M. R. Bhandari, *Testing of the Efficacy of Some Materials Against Weevil in Stored Maize*, PAC Working Paper, Dhankuta. Nepal, 1996.
- [13] U. Reddy and S. Reddy, "Effectiveness of selected plant material as protectants against infestation and nutrient components during storage of green gram (*Vigna radiate*)," *Bulletin of Grain Technology*, vol. 25, no. 1, pp. 48–56, 1978.
- [14] J. Shrestha, S. Subedi, R. Acharya, S. Sharma, and M. Subedi, "Grain yield stability of maize (*Zea mays* L.) hybrids using ammi model and GGE Biplot analysis," *SAARC Journal of Agriculture*, vol. 19, no. 2, pp. 107–121, 2022.
- [15] A. Padmasri, C. Srinivas, K. Vijaya Lakshmi et al., "Management of rice weevil (*Sitophilus oryzae* L.) in maize by botanical seed treatments," *International Journal of Current Microbiology and Applied Sciences*, vol. 6, no. 12, pp. 3543–3555, 2017.
- [16] D. J. Saville, "Multiple comparison procedures-cutting the gordian knot," *Agronomy Journal*, vol. 107, no. 2, pp. 730–735, 2015.
- [17] R. B. Paneru, V. R. Duwadi, R. Khanal, and M. R. Bhattarai, *Testing of the Efficacy of Some Local Materials against Weevil in Store Maize*, PAC Working Paper 139, PAC, Dhankuta c/o BAPSO PO Box 106, Kathmandu, Nepal, 1997.
- [18] K. D. Ileke and O. C. Ogungbite, "Entomocidal activity of powders and extracts of four medicinal plants against *Sitophilus oryzae* (L.), *Oryzaephilus Mercator* (Faur) and *Rhizopertha dominica* (Fabr.)," *Jordan Journal of Biological Sciences*, vol. 7, no. 1, pp. 57–62, 2014.
- [19] J. M. Adesina, A. R. Jose, Y. Rajashaker, and L. A. Afolabi, "Entomototoxicity of *Xylopiya aethiopica* and *Aframomum melegueta* in suppressing oviposition and adult emergence of *Callasobruchus maculatus* (Fabricus) (Coleoptera: chrysomelidae) infesting stored cowpea seeds," *Jordan Journal of Biological Sciences*, vol. 8, no. 4, pp. 263–268, 2015.
- [20] F. Chebet, A. L. Deng, J. O. Ogendo, A. W. Kamau, and P. K. Bett, "Bioactivity of selected plant powders against *Prostephanus truncates*," *Plant Protection Science*, vol. 49, no. 1, pp. 34–43, 2013.
- [21] D. R. Panthee, "Efficacy of different indigenous pesticides for wheat seed storage," *Journal of Agriculture and Animal Science, Rampur. Chitwan*.vol. 17-18, pp. 71–76, 1997.

- [22] B. K. Shrestha, 2006, [https://issuu.com/irishmikeew.wigwigan/docs/oasp\\_proceedings](https://issuu.com/irishmikeew.wigwigan/docs/oasp_proceedings).
- [23] S. Kumar, *Survey of Indigenous Technologies and Evaluation of Botanicals against Major Storage Pests*, University of Agriculture Science, Dharwad, India, 2003.
- [24] D. C. Kudachi, *Management of Lesser Grain Moth, *Rhizopertha dominica* (Fab.) and Rice Weevil, *Sitophilus Oryzae* (Linn.) in Stored Sorghum*, University of Agriculture Science, Dharwad, India, 2008.
- [25] Y. D. Gc, "Efficacy of indigenous plant materials and modified storage structures to insect pests of maize seed during on-farm storage," *Journal of the Institute of Agriculture and Animal Science*, vol. 27, pp. 69–76, 2006.
- [26] R. B. Thapa and R. B. Paneru, "Efficacy of plant materials and storage containers against maize weevil, *Sitophilus zeamais* (Mots.) in maize storage," *International Journal of Agriculture Environment and Biotechnology*, vol. 3, no. 1, pp. 119–128, 2018.
- [27] R. B. Paneru, V. R. Duwadi, and M. R. Bhattarai, *Second year to testing locally available plant material against *S. oryzae* in stored wheat*, Pakharibas Agriculture Centre Work Paper, Dhankuta, Nepal, 1993.
- [28] G. Jilani, *Use of Botanicals for Protection of Stored Food Grain against Insect Pests – A Review Work Done at Grain Storage Research Laboratory*, PARC, Karachi, Pakistan, 1984.
- [29] B. S. Biradar, *Prevention of Cross Infestation by *Sitophilus oryzae* Linn. and *Rhizopertha Dominica* Fab in Stored Wheat*, University of Agriculture Science, Dharwad, India, 2000.
- [30] P. R. Kalasagond, *Management of Beetle Pests in Stored Wheat by Non-Insecticidal Approaches*, University of Agriculture Science, Dharwad, India, 1998.
- [31] Y. P. Sah, *Minimizing the Losses in Stored Maize Under Farmers' Storage Condition in the Eastern Hills of Nepal*, "ARSP Technical Paper No. 188, Agricultural Research Station, Dhankuta, Nepal, 1999.
- [32] H. Regmi, L. Kafle, Y. Dhoj Gc, and C. J. Shih, "Efficacy of natural products against *Callosobruchus chinensis* (Coleoptera: bruchidae) in Nepal," *Journal of Economic Entomology*, vol. 105, no. 3, pp. 1095–1099, 2012.