

Research Article

Evaluation of Botanical Powders for the Management of Rice Weevil (*Sitophilus oryzae* L. Coleoptera: Curculionidae) in Rupandehi, Nepal

Dipak Khanal ¹, Subin Babu Neupane,¹ Archana Bhattarai,² Swarnima Khatri-Chhetri,² Nisha Nakarmi,² Sarita Sapkota,² Bivekananda Mahat,² Pushpa Pandey,¹ and Vinita Sharma³

¹Institute of Agriculture and Animal Science, Tribhuvan University, Kirtipur, Nepal

²Ministry of Agriculture and Livestock Development, Kathmandu, Nepal

³Nepal Agriculture Research Council, Kathmandu, Nepal

Correspondence should be addressed to Dipak Khanal; dipakbabu@hotmail.com

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An experiment to manage rice weevil (*Sitophilus oryzae* L. Coleoptera: Curculionidae) in wheat (*Triticum aestivum* L. Gramineae) was carried out at Institute of Agriculture and Animal Science (IAAS), Paklihawa Campus, Rupandehi, Nepal. The experiment was conducted under completely randomized design (CRD) with seven treatments viz. neem leaf dust (*Azadirachta indica* A. Juss) 15 g/kg, tobacco leaf dust (*Nicotiana tabacum* L.) 10 g/kg, ginger rhizome powder (*Zingiber officinale* Roscoe) 20 g/kg, garlic cloves powder (*Allium sativum* L.) 20 g/kg, Sichuan pepper seed powder (*Zanthoxylum armatum* Roxb.) 10 g/kg, sweet flag rhizome dust (*Acorus calamus* L.) 5 g/kg, and control with three replication. Result revealed that the highest mortality of weevils was observed in the wheat seed treated with *A. calamus* (98.33%), followed by *N. tabacum* (85.67%), *A. sativum* (73.34%), *A. indica* (70.67%), *Z. armatum* (70.34%), and *Z. officinale* (58.34%). Similarly, the lowest percent weight loss (3.32%) and damage of seed (4.0%) were observed in wheat treated with *A. calamus*. Moreover, the highest germination (89%) was observed in seeds treated with *A. calamus* rhizome powder when tested at 90 days after treatment application. Based on weevil mortality and the germination test, it is found that sweet flag rhizome powder is the best treatment against rice weevil followed by tobacco leaf dust and garlic clove powder. Therefore, these botanicals could be one of the effective alternatives for the management of weevil especially to the farmers who do not use chemical insecticides in the rural areas of Nepal.

1. Introduction

In Nepal, wheat (*Triticum aestivum* L.) is the third ranking cereal crop after rice (*Oryza sativa* L.) and maize (*Zea mays* L.) in terms of area of production and productivity. Wheat occupies about 22.58% of the total area in the cereal production and contributes 20.13% of the total cereal production [1]. This crop is grown in most of the agroclimatic regions from Terai (tropical plain area) to foothills of mountains in Nepal [1]. Wheat is believed to be originated in southwestern Asia [2]. Wheat is considered nutritionally better than other cereals as it contains more protein, and it

has a relatively high amount of amino acids [3]. Insects such as *Sitophilus* spp, *Tribolium* spp, *Rhizopertha* spp, and *Sitotroga cerealella* are major stored grain pests in Nepal. It is reported that the loss due to different insect pests and postharvest handling is around 15–20% of total grain production in Nepal [4]. The estimated postharvest loss of food grains due to insect pests in Nepal in traditional storage conditions is 5.5% [5]. Among these insects, rice weevil *Sitophilus oryzae* L. is the most ubiquitous, and it severely damages a range of cereals such as wheat, maize, and rice [6]. When wheat is stored for long time for human consumption or seed, it is prone to get infested by *S. oryzae* that eventually

leads to severe economic loss as the quantity and quality of stored wheat are largely compromised. Both larva and adult of the weevil are capable of damaging the wheat by boring and feeding on the grains. Such damage is often accelerated along with high grain moisture content (>12%), high relative humidity (>70%), and high temperature (>27°C) by favoring the growth and development of the weevils.

The study of the efficacy of some botanicals against various insects has been carried out by many researchers [7, 8]. In Nepal, Bhusal and Sharma used different combination and concentrations of botanicals of which some are effective against this pest [8, 9]. The botanicals used for these studies are traditionally popular for their culinary as well as medicinal purpose in Nepal. Although the mechanism of these botanicals in controlling the insects and pests are not very clear, efforts have been made to estimate their efficacy in controlling the insects in various experiments in Nepal. As these plants have antifeedant, repellent, and pesticidal properties against insects, various local products made from such plants are found to be very effective in controlling stored grain pests especially in small scale. While some of these plants have growth disrupting properties as well [10].

Among the common botanicals used as pesticides, the *Zanthoxylum armatum* DC, Timur in Nepalese language, is grown extensively in the hills of Nepal and is also a common plant in southeast Asia. Its seed is popular for its strong volatile smell; so, it is used for culinary purposes and is known to be traditionally used as a repellent against different insect pests. Similarly, *Acorus calamus* L. is grown in marshy land from the Terai (topical plain area) to the hills of Nepal. It is popularly used as medicine for sore throat and cold traditionally. Similarly, *A. calamus* powder is used to control stored grain pests on various cereals in Nepal. Paneru et al. reviewed about properties of *A. calamus* and stated that β -asarone found in stolons has an insecticidal property, whereas dried rhizome possesses antifeedant property [11, 12]. Garlic (*Allium sativum* L) and Zinger (*Zingiber officinale* Roscoe) are popular herbs grown from plains to high hills of Nepal. Garlic and zinger own an important place in the Nepalese kitchen, and these are also traditionally used as medicine for abdominal pain, several digestive health issues, and common cold and in some cases used for pest management. Likewise, neem (*Azadirachta indica* A. Juss) is another popular plant of subtropical and tropical regions of Nepal. The leaves of this plant are popular for insect control since a long period of time. Moreover, the nicotine, extract from the tobacco (*Nicotiana tabacum* L.), is being used as an insecticide against many pest since a long. The nicotine is very effective against insects causing the uncontrolled nerve firing and masking acetylcholine [13]. Complete reliance on a chemical has led to insecticide resistance within the insects, and insects have become more and more adapted to these chemicals [14]. On the other hand, the issues related to the persistence of chemical on the treated grains and also their toxicity to natural enemies of these insects are equally dangerous in many ways. Similarly, other problems caused by chemical pesticides are insect resurgence, secondary pest outbreak, health hazard to human beings, and the environment. This led us to refocus the way we think and

encouraged us to conduct research for a pest management program that is safer, economical, and scientifically justifiable. In rural Nepal, farmers lack proper knowledge on techniques of grain protection in storage, and they often practice other risky methods of protection of stored grains. They use synthetic pesticides such as malathion and aluminium phosphide to protect their stored grains which can cause health hazards. Hence, the plant products which have insecticidal properties present within them are a very good alternative to protect stored grains instead of these hazardous synthetic pesticides [15]. The major objective of our study is to devise an effective and ecofriendly alternative of chemical insecticides to control rice weevil in stored grains in Nepal.

2. Materials and Methods

The research was conducted at the laboratory of the Department of Entomology, Paklihawa Campus, Rupandehi, Nepal, in 2015. The laboratory is located at the geographical coordinates of 27° 30' 0" North, 83° 27' 0" East. The average temperature and relative humidity during the experiment period was 32°C (ranging from 29°C to 35°C) and 70 ± 5%, respectively. The room was well ventilated to allow enough air circulation throughout the room.

2.1. Materials. Plastic made insect rearing box (one liter capacity), with a perforated lid was used to store 250 g of wheat. The plastic container was covered with a muslin cloth to ensure air circulation and to prevent the escape of inoculated weevil from the box. An aspirator was used to collect insects into the vial. maximum and minimum digital thermometer was used to detect the temperature of the laboratory during the study period. A digital RH meter was used to measure humidity in the lab. An electronic weight scale (Changzhoo Accurate Weight Co., Ltd.) of measuring capacity up to 350 g and 3 digits more behind decimal point was used to weight the test seeds.

2.2. Sampling of Wheat Grains. Gautam (BL 1887) variety of wheat (released by Nepal Agriculture Research Council in 2002) was used in the entire test. Gautam is a high yielding variety recommended for the Terai, tars, and lower valleys of Nepal to grow in irrigated land as a timely or late sown variety. Using the results from a preliminary survey, this variety was found as most popular among farmers in Rupandehi because of its bold grain, taste, flour quality, and milling quality for making "chapatti" (local bread). Thus, the seed was collected from local farmers for this research. The sample wheat was disinfected by hot air treatment, and infestation free grains were used in the experiment.

2.3. Preparation of Botanicals. All the botanicals used in the experiment viz. leaf of neem and tobacco, rhizomes of sweet flag and zinger, garlic cloves, and Sichuan pepper seed were collected from farmers field, dried in the shade, and powdered using a grinder. Those botanicals were applied in the

following dosage: *Nicotiana tabacum* L. 10 g/kg, *Zingiber officinale* Roscoe 20 g/kg, *Allium sativum* L. 20 g/kg, *Azadirachta indica* A. Juss 15 g/kg, *Zanthoxylum armatum* DC. 10 g/kg, *Acorus calamus* L. 5 g/kg, and control (not treated with any materials). The digital balance was used in weighing purpose.

2.4. Collection, Mass Rearing, and Inoculation of *S. oryzae*. The initial stock of adult weevils was collected from local farmers of Bhairahawa. The weevils were later identified as the *S. oryzae* L. in the laboratory. Mass rearing of weevils was performed to achieve uniform aged weevil stock of the second generation under controlled lab environment at 27°C, 85% RH, and 14:10 day night ratio in the Entomology lab of Paklihawa Campus for three weeks. Two hundred and fifty grams of the sample wheat were treated with botanical powder at 5–20 g/kg of grain, taken in a small plastic container (capacity 500 g), and 50 pairs/treatment of *S. oryzae* belonging to the second generation were released in the wheat, as the new stock of weevils would be more active, vigorous, and prolific, and they would be more liable to damage more wheat than the old stock.

2.5. Germination Test. The germination of seeds was made using a random sample of hundred grains of each treatment and replication before and after treatment application. The seeds were cleaned properly and distributed homogeneously in well-soaked blotting paper in Petri dishes (8.8 cm diameter). All Petri dishes were then placed in a germination chamber at a normal room temperature of 27°C. Blotting paper was used as a germination medium because it has a lower risk of getting mold infestation, it is easier to handle than sand and soil, but it still permits penetration of the radical that provides a better evaluation of abnormal germination. Moreover, moisture also does not stratify within the paper medium as it might do so if sand or soil was used. Finally, the germinated seeds were counted, and the germination percentage was calculated using the following equation:

$$\text{germination percentage} = \left[\frac{(\text{number of germinated seeds})}{(\text{total number of seeds})} \right] \times 100. \quad (1)$$

Additionally, counts were also taken for physically damaged grains and intact grains for 100 randomly sampled seeds, and weight loss comparison was also made for the seeds used in the experiment both before and after treating with botanicals in these seeds.

2.6. Statistical Analysis. Data were subjected to analysis of variance (ANOVA) and significant differences existed; treatment means were compared at 0.05 significant level using the DMRT test. Arcsine data transformation was conducted whenever required to satisfy the assumptions of ANOVA [16]. Data were analyzed using MS-EXCEL 2007 and R-Stat 3.5.0 (R core team 2013).

3. Results and Discussion

3.1. Effect of Botanicals on Mortality of *S. oryzae*. Among the six different botanicals tested for the mortality test of rice weevil, rhizome powder (5 g/kg) was found to cause the highest mortality (98.33%) at 14 days after treatment (DAT) which was followed by tobacco leaf powder (10 g/kg) (85.67%), neem leaf powder (15 g/kg) (70.67%), garlic clove powder (20 g/kg) (73.34%), Sichuan pepper seed powder (20 g/kg) (70.34%), and the ginger powder (58.34%). While, lowest weevil mortalities were obtained in control which was only 3.66% (Table 1).

Even in previous experiments, it was evident that the powder of *A. calamus* was very effective to maize weevil at 2 g, 1 g, and 0.5 g/100 g of maize grain in which 100% mortality was seen at 8th and 10th days after treatment application [17]. Similar results were obtained in another experiment where 100% mortality of *S. oryzae* L. was obtained when weevil was treated with *A. calamus* at 3 g/kg of wheat grain [18]. Similarly, in another test conducted against Angoumois grain moth, (*Sitotroga cerealella* O.), it was found that 100% mortality was resulted when rhizome dust of *A. calamus* was used at 10 g/kg of rice grain [19]. *A. calamus* dust was also found to have excellent efficacy in controlling *Callosobruchus chinensis* L. [20]. In another experiment, *A. calamus* was even found more effective than malathion at 1 g/kg in controlling pulses beetle *C. chinensis* for up to two generations [21]. This indicates that *A. calamus* could be used as a safer alternative to commonly used commercial pesticides.

3.2. Effect of Botanicals on Percent Germination, Seed Damage, Weight Loss, and Live Weevil Population at 90 DAT. The mean germination of wheat was 95% before the seeds were treated in the experiment. When the germination test was performed at 90 DAT, the germination percent was significantly higher in *A. calamus* (89%) treated wheat than in control (23.66%) (Table 2). Apart from germination, the physical damage of wheat seed was quantified by counting the weevil bored seeds and intact seeds in a randomly sampled 100 grains from all the treated wheat stock. The physical damage percentage was lowest in wheat treated with *A. calamus* (4%) which was followed by *N. tabacum* (14.33%) treated wheat seed. Furthermore, the percentage of seed damage was recorded highest in the control, i.e., 83% (Table 2). On quantifying the percent weight loss of wheat, the highest percentage of weight loss was recorded in control (50.95) and lowest was recorded in *A. calamus* (3.32%) treated wheat seed (Table 2).

Most of the findings of this study lie closely in accordance with the finding of some previously conducted experiments. For example, extracts of *N. tabacum* were found effective in controlling the various stages of maize weevil (*Sitophilus zeamays* M.) [22]. *A. sativum* demonstrated to have great potential at reducing the population of *S. oryzae* in some cereals [23]. Similarly, the progeny emergence of maize weevil and cowpea weevil (*Callosobruchus maculatus* F.) was low in *A. sativum* treated grains as compared to the

TABLE 1: Effect of botanicals on mortality of *S. oryzae* in wheat tested at Rupandehi, Nepal, in 2015.

Treatments	Percent mortality of weevil at			
	3 DAT	7 DAT	10 DAT	14 DAT
<i>Azadirachta indica</i> , 15 g/kg	46.67 ^c (43.09) ± 1.20	61.34 ^c (51.55) ± 0.67	66.67 ^c (54.74) ± 0.88	70.67 ^c (57.21) ± 0.88
<i>Nicotiana tabacum</i> , 10 g/kg	61.00 ^b (51.35) ± 0.58	76.67 ^b (61.12) ± 0.67	81.67 ^b (64.65) ± 0.67	85.67 ^b (67.75) ± 0.33
<i>Zingiber officinale</i> , 20 g/kg	40.67 ^d (39.61) ± 2.19	51.00 ^d (45.57) ± 1.53	55.34 ^d (48.06) ± 1.33	58.34 ^d (49.80) ± 1.20
<i>Allium sativum</i> , 20 g/kg	49.67 ^c (44.80) ± 2.40	64.67 ^c (53.53) ± 1.33	69.67 ^c (56.59) ± 1.45	73.34 ^c (58.92) ± 1.45
<i>Zanthoxylum armatum</i> , 10 g/kg	50.34 ^c (45.19) ± 2.40	62.00 ^c (51.95) ± 2.08	66.67 ^c (54.75) ± 2.03	70.34 ^c (56.80) ± 1.45
<i>Acorus calamus</i> , 5 g/kg	68.67 ^a (55.98) ± 2.03	88.34 ^a (70.05) ± 0.88	94.00 ^a (75.85) ± 0.58	98.33 ^a (82.66) ± 0.33
Control	1.34 ^e (6.53) ± 0.33	2.67 ^e (9.35) ± 0.33	3.00 ^e (9.88) ± 0.58	3.66 ^e (11.01) ± 0.33
Mean	45.47 (40.93)	58.09 (49.02)	62.42 (52.07)	65.76 (54.88)
<i>P</i> value	<0.001	<0.001	<0.001	<0.001
CV (%)	4.49	2.51	2.33	2.18
LSD	3.27	2.19	2.16	2.13

Mean in the same column with same letter is not significantly different at $P < 0.05$. Figures in parentheses represent arcsine transformed data.

TABLE 2: Effect of botanicals on percent germination, seed damage, weight loss, and live weevil population in 90 DAT at Rupandehi in 2015.

Treatments	% germination	% seed damage	% weight loss	Weevil population
<i>Azadirachta indica</i> , 15 g/kg	80.66 ^b ± 1.45	21.66 ^c ± 0.88	19.78 ^c ± 1.10	391.33 ^b ± 9.86
<i>Nicotiana tabacum</i> , 10 g/kg	80.66 ^b ± 1.76	14.33 ^f ± 0.88	15.62 ^d ± 0.42	205.00 ^d ± 7.77
<i>Zingiber officinale</i> , 20 g/kg	58.33 ^d ± 2.03	39.00 ^b ± 2.08	25.18 ^b ± 1.44	394.33 ^b ± 6.23
<i>Allium sativum</i> , 20 g/kg	80.33 ^b ± 0.88	32.66 ^c ± 0.67	16.70 ^{cd} ± 0.52	281.66 ^c ± 4.41
<i>Zanthoxylum armatum</i> , 10 g/kg	66.00 ^c ± 1.53	26.66 ^d ± 0.88	13.79 ^d ± 0.71	255.00 ^c ± 7.64
<i>Acorus calamus</i> , 5 g/kg	89.00 ^a ± 0.58	04.00 ^g ± 0.58	3.32 ^e ± 0.58	51.33 ^e ± 5.55
Control	23.66 ^e ± 0.88	83.00 ^a ± 2.08	50.95 ^a ± 2.20	646.66 ^a ± 10.64
Mean	68.38	31.61905	20.76	306.19
<i>P</i> value	<0.001	<0.001	<0.001	<0.001
CV (%)	3.59	5.62	9.23	5.42
LSD	4.37	3.081307	3.41	29.53

grains without any protectant used [24]. Garlic also performed better in reducing the number of holes per seed, number of damaged seeds, percentage damaged seeds, and weight loss of beans infected with *Phaseolus vulgaris* L. tested against bean bruchid (*Zabrotes subfasciatus* Boh) compared to no pesticide application treatment [25]. Botanicals are easily available herbal plants, which have almost no adverse effects on human health and the environment. We agree that some traditionally used botanicals can be an excellent alternative to chemical pesticides in stored grains if used in the correct dose and method. The ease in availability and simplicity in these botanicals are most likely to be accepted and adopted by the farmers in Nepal [26]. Apart from sweet flag, most other herbs used in this experiment have been found to be very effective in controlling various other stored insect pests and which has been mentioned in many reports.

4. Conclusion

Among botanical materials tested, it is found that three safe botanical materials such as *A. calamus* rhizome dust, *A. sativum* clove powder, and *N. tabacum* leaf dust can be explored as excellent alternatives over the poisonous pesticides for the management of rice weevil in wheat grain storage. These ecofriendly treatments could be accessible and economically viable alternatives to hazardous chemical pesticides in integrated insect pest management in rural Nepal. However, testing over three generations' weevils in

laboratory research is slightly inadequate in drawing conclusions about the effectiveness of these botanical powders. So, they must be evaluated under different climatic conditions and different ecological zones as per need to expand their uses in a wide variety of stored seeds.

Data Availability

The data used to support the findings of this study are available from the corresponding author upon request.

Conflicts of Interest

The authors declare that there are no conflicts of interest.

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References

- [1] ABPSD, *Statistical Year Book Nepal*, Central Bureau of Statistics, National Planning Commission, Government of Nepal, Kathmandu, Nepal, 2015.
- [2] L. Gibson and G. Benson, *Origin, History, and Uses of Oat (Avena sativa) and Wheat (Triticum aestivum)*, Iowa State University, Department of Agronomy, Ames, IA, USA, 2002.

- [3] P. Kumar, R. Yadava, B. Gollen, S. Kumar, R. K. Verma, and S. Yadav, "Nutritional contents and medicinal properties of wheat: a review," *Life Sciences and Medicine Research*, vol. 22, pp. 1–10, 2011.
- [4] F. P. Neupane, "Agricultural entomology in Nepal," *Review of Agricultural Entomology*, vol. 83, no. 12, pp. 1291–1304, 1995.
- [5] P. S. Tyler, *Misconception of Food Losses*, Tropical Stored Products Centre, Tropical Products Institute, Berkshire, UK, 1985.
- [6] S. K. Bhatia, V. S. Singh, and M. G. Bansal, "Varietal resistance in barley grain to laboratory infestation of rice weevil and lesser grain borer," *Bulletin of Grain Technology*, vol. 13, no. 2, pp. 69–72, 1975.
- [7] Y. Huang, S.-H. Ho, H.-C. Lee, and Y.-L. Yap, "Insecticidal properties of eugenol, isoeugenol and methyleugenol and their effects on nutrition of *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) and *Tribolium castaneum* (Herbst) (Coleoptera: Tenebrionidae)," *Journal of Stored Products Research*, vol. 38, no. 5, pp. 403–412, 2002.
- [8] V. Sharma, R. B. Thapa, Y. G. C. Dhoj, and L. P. Amagain, "Screening of different wheat varieties against rice weevil, *Sitophilusoryzae* L., (Coleoptera: Curculionidae)," *Journal of Plant Protection Society*, vol. 1, pp. 23–29, 2008.
- [9] P. Bhusal, "Eco-friendly management of potato tuber moth, *Phthorimaea operculella* (zeller) (Lepidoptera: Gelechiidae) in rustic stores," *IAAS Journal*, vol. 4, pp. 90–110, 2013.
- [10] N. Kulkarni and K. C. Joshi, "Antifeedant properties of some botanical extracts against Maharukha webworm, *Attevafabriciella* Swed. (Lepidoptera: Yponomeutidae)," *Journal of Tropical Forest Products*, vol. 4, no. 1, pp. 11–16, 1998.
- [11] R. B. Paneru, G. N. J. Le Patourel, and S. H. Kennedy, "Toxicity of *Acorus calamus* rhizome powder from Eastern Nepal to *Sitophilus granarius* (L.) and *Sitophilus oryzae* (L.) (Coleoptera, Curculionidae)," *Crop Protection*, vol. 16, no. 8, pp. 759–763, 1997.
- [12] H. P. Chen, K. Yang, L. S. Zheng, C. X. You, Q. Cai, and C. F. Wang, "Repellant and insecticidal activities of shyo-bunone and isoshyo-bunone derived from the essential oil of *Acorus calamus* rhizomes," *Pharmacognosy Magazine*, vol. 11, no. 44, pp. 675–681, 2015.
- [13] I. Ujváry, "Nicotine and other insecticidal alkaloids," in *Nicotinoid Insecticides and the Nicotinic Acetylcholine Receptor*, I. Yamamoto and J. E. Casida, Eds., Springer, Tokyo, Japan, pp. 29–69, 1999.
- [14] W. Brogdon and J. C. McAllister, "Insecticide resistance and vector control," *Emerging Infectious Diseases*, vol. 4, no. 4, pp. 605–613, 1998.
- [15] R. Rajapakse, S. G. J. N. Senanayake, and D. Ratnasekera, "Effect of five botanicals on oviposition, adult emergence and mortality of *Callosobruchusmaculatus* Fabr. (Coleoptera: Bruchidae) infesting cowpea, *Vignaunguiculata* L. Walp," *Journal of Entomological Research*, vol. 22, no. 2, pp. 117–122, 1998.
- [16] K. A. Gomez and A. A. Gomez, *Statistical Procedures for Agricultural Research*, John Willey and Sons. Inc., New York, NY, USA, 1984.
- [17] NARC, "Entomology division," Annual Report, Nepal Agriculture Research Council, Kathmandu, Nepal, 1996.
- [18] S. Bala and A. Vyas, "Biology and ecofriendly management of rice weevil *Sitophilus oryzae* (LIN.) in stored sorghum," *Journal of Sciences-Life Sciences*, vol. 8, pp. 976–7436, 2016.
- [19] G. P. Timsina, A. S. R. Bajracharya, Y. P. Sah, D. L. Mandal, and S. N. Mehta, "Assessment of storage losses of maize by angoumois grain moth (*Sitotroga cerealella* oliver) and weevil (*Sitophilus* spp. Linn) in farmers' storage condition," in *Proceedings of Twenty-Fifth National Summer Crop Workshop on Maize Research and Production*, pp. 263–267, Kathmandu, Nepal, June 2007.
- [20] H. Regmi and Y. G. C. Dhoj, "Eco-friendly management of pulse beetle," *The Journal of Agriculture and Environment*, vol. 12, pp. 60–82, 2011.
- [21] H. Regmi, L. Kafle, G. C. Y. Dhoj, and C. J. Shih, "Efficacy of natural products against *Callosobruchuschinensis* (Coleoptera: Bruchidae) in Nepal," *Journal of Economic Entomology*, vol. 105, no. 3, pp. 1095–1099, 2012.
- [22] J. E. Idoko and R. A. Adebayo, "Efficacy of single and combined leaf powder of *Nicotiana tabacum* L. Solanales: Solanaceae with reduced rates of pirimiphos-methyl in management of *Sitophilus zeamais* Motschulsky [Coleoptera: Curculionidae]," *Journal of Agricultural Science*, vol. 3, no. 1, pp. 276–280, 2011.
- [23] N. Abhijith, S. Mohan, and S. J. Nelson, "Bioassay to detect the toxicity of sweet flag (*Acorus calamus*) 6 EC formulation against pests of stored spices viz., rusty grain beetle, *C. ferrugineus* (Stephens) cigarette beetle, *L. serricornis* (F.) and red flour beetle, *T. castaneum* (Herbst)," *Journal of Entomology and Zoology Studies*, vol. 6, no. 5, pp. 1921–1924, 2018.
- [24] E. F. Asawalam and L. Onu, "Evaluation of some plant powders against Khapra beetle (*Trogoderma granarium* Everts) (Coleoptera: Dermestidae) on stored groundnut," *Advancement in Medicinal Plant Research*, vol. 2, no. 2, pp. 27–33, 2014.
- [25] L. S. Mulungu, E. N. Luwondo, S. O. W. M. Reuben, and R. N. Misangu, "Effectiveness of local botanicals as protectants of stored beans (*Phaseolus vulgaris* L.) against bean bruchid (*Zabrotes subfasciatus* Boh) (Genera: Zabrotes. Family Bruchidae)," *Journal of Entomology*, vol. 4, no. 3, pp. 210–217, 2007.
- [26] D. Pimentel, "World resource and food losses to pests," in *Ecology and Management of Food-Industry Pests*, J. R. Gorham, Ed., AOAC, pp. 5–11, Rockville, MD, USA, 1991.