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Biorational approaches for the management of rice weevil *Sitophilus oryzae* (L.) in cereal grains

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Abstract
Rice weevil, *Sitophilus oryzae* is the primary pest of cereal grains;both larval and adult stages internally damage the cereal grains like paddy, wheat, maize and sorghum. It causes excellent monetary loss up to 100% in maize, unhusked paddy 69% and 83.5% in sorghum both in quality and quantity. Damage results in lessening the grain weight, loss of nutritional elements and germination of seeds. Many food grains are flawed after harvest due to a lack of enough storage and processing facilities. Currently, chemical control is the most commonly used approach against pests. Lots of chemicals that are toxic to stored-grain pests, including insecticides such as organophosphates, synthetic pyrethroids and fumigants such as methyl bromide and aluminum phosphide are still in use for their management. Use of insecticide is a straight forward and economical approach, but due to its toxic effects like residues, resistance, it is an unsafe for environment and human consumption. In search of alternatives, plant product like sweet flag rhizome powder @ 5% was found to cause100 percent adult mortality and recorded higher seed germination (85.67%) in sorghum. Eucalyptus oil recorded the most increased mortality of 26.1% in fumigation assay; Nano-formulation gives cent percent mortality three days after treatment at @ 250 and 125 ppm kg^{-1} in maize. Growth regulators like Buprofezin at 300 ppm in rice grains reduce progeny number and reducing weevil populations by 98% by pteromalidslike *L. distinguendus.*

Keywords: biocontrol agents, botanicals, nano-formulations, rice weevil, resistant varieties

Introduction
Human meals mostly consist of cereal grains. Grain losses in cereals during storage can reach 50% of the total harvest, with insects accounting for the majority of the quantitative and qualitative losses (Fornal *et al*. 2007) [13]. Cereal grains become susceptible to insect pests, which cause quantitative and qualitative losses due to more extended storage periods before being processed, consumed, or transported (Nagpal and Kumar, 2012) [18]. In tropical agriculture, losses of cereal grains by insect pests can approach 30% due to a lack of efficient storage facilities and the high humidity of the tropics (Ramputha *et al*. 1999) [22]. Food Corporation of India (FCI) has a storage capacity of about 28 million tons, compared to 60–70 million tons in India. Sitophilus spp. (Linn) is the world's most damaging insect pest of stored uncooked wheat grains (Champ and Dyte, 1976) [6]. It is a pest of stored cereal grains that is ubiquitous, phytosanitary, and quarantined. The weevil is found worldwide in warm and tropical climates, and it has a global range (Hong *et al*. 2018) [15].

Pest Status
In *Sitophilus zeamais* (Motsch) and *Sitophilus oryzae* (L.), causes substantial losses to stored maize, ranging from 18.30 percent (Adams, 1976) [1] to 92.40 percent (Bitran *et al*. 1978) [5] in various areas of the world excluding India. *Sitophilus oryzae* (L.) is, on the other hand, the most destructive insect pest to cereal grains during storage (Nwaubani *et al*. 2014) [19]. *S. oryzae* (L.) causes massive losses in stored maize in India and other world areas, up to 100%. (Singh *et al*. 1974) [25]. Rice weevil infestation has caused damage to sorghum grains of up to 83.5 percent in six months (Kudachi and Balikai, 2014) [17]. Unhusked rice samples from six districts in Himachal Pradesh were found to be infected with *S. cerevisiae*. Oryzae was found to be present in 69 percent of the samples. Because of S., I've lost a lot of weight. The percentage of oryzae in the sample ranged from 1.09 to 3.10 percent, with an average of 2.11 percent (Thakur and Sharma, 1996) [26]. This clearly demonstrates the significance of *S. oryzae* is a kind of oryzae found in cereal grains. By creating a tiny hole in the seed, the female insect can place an egg and cover it with gelatinous substance. The apodus grub feeds inside the grain, pupates there, and adults emerge from the hole formed on the seed (David and Kumaraswami, 1975) [28], and damage is multiplied by a factor of ten during storage (David and Kumaraswami, 1975) [28].

Biorational Approaches
The world depends primarily upon applications of synthetic pyrethroid, organophosphorus insecticides and the fumigants (i.e., Aluminum Phosphide and phosphine gas) Control of the stored grain insects. Contact insecticides and fumigants have been used for a long time to protect stored products from insect pests (Daglish, 2006) [7].
In response to growing market demand for foodstuffs that are free of pesticide residues and because stored-product insects are developing resistance to insecticides, such chemicals have remained under increasingly restrictive policies over the past years (Kljajic and Peric, 2005) [16].
New trends and safe means in the management of stored grain insects are desirable and have become a challenge.

Because of the negative effects of synthetic insecticides, substances of plant origin for the control of stored grain insects are quite capable as they are more biodegradable, less toxic to human beings and safe for the environment (Guzzo *et al.* 2006) [14]. The plant materials are possessing insecticidal as well as repellent properties with little or no mammalian toxicity (Reddy and Reddy, 1978) [23]. Development of resistance in rice weevil to chemicals hampers the management of pest, and substitute methods of management are necessary (Ribeiro *et al.* 2013) [24].

a. Plant and Animal Products

Sweet flag rhizome powder @ 5 percent was found significantly superior in reducing 100 percent adult mortality, no seed damage, weight loss and higher seed germination (85.67 percent) followed by neem seed kernel powder @ 5 percent with significant maximum adult mortality (85.00 percent), least seed damage (13.00 percent), lowest seed weight loss (5.16 percent) and higher germination percentage (74.33 percent) against rice weevil, *Sitophilus oryzae* for six months in stored sorghum seeds (Bhargude *et al*. 2021) [4]. Sweet flag powder 5 percent, custard apple seed powder 5 percent and neem seed kernel powder 5 percent evaluated in against *Sitophilus oryzae* in sorghum grains after 30 and 60DAS no grain damage found and lakke leaf powder 5 percent gives 20.50 percent damage (Bhanderi *et al*. 2015) [3]. Seeds treated with *Acorus calamus* rhizome powder @ 10 g kg^{-1} seed recorded the highest germination percentage (85.67), seedling vigor index (2354), less infestation (0.18 per cent) and weight loss (0.02 per cent) at the end of nine months of storage against *Sitophilus oryzae* in maize (Padmasri *et al*. 2017) [1]. Contact and fumigant essential oils, like orange oil, eucalyptus oil and cinnamon oil against rice weevil, *Sitophilus oryzae* (L.). In contact bioassay at 24 h after treatment, the highest mortality (95.8 percent) was recorded at 0.75 µl/cm2 with eucalyptus oil, followed by orange oil (93.40 percent), which was at par with eucalyptus oil (93.2 percent) at 0.50 µl/cm^2. In fumigation assay also, eucalyptus oil recorded the highest mortality of 26.1 percent followed by orange oil (13.3 percent) and cinnamon oil (10.43 percent) after 24 h exposure at the highest concentration used in the study 2 µl/cm^2 (Patil *et al*. 2016) [21]. *Olax zeylanica* leave powder tested at four different doses (1.0g, 3.0g, 5.0g and 7.0g) for fumigant repellency in a dual-choice bio-assay apparatus against the rice weevil, *Sitophilus oryzae*. The highest repellent effect was produced by 7.0g of leaf powder resulting in repellency of 97 percent, while the lowest dose (1.0g) also elicited more than 50 percent repellency in weevils indicating a very strong repellent action of the powdered leaves (Fernando and Karunaratne, 2013) [12]. Highest mortality of weevils was observed in the wheat seed treated with *A. calamus* (5g/kg) 98.33 percent, followed by N. tabacum (10g/kg) 85.67 percent, *A. sativum* (20g/kg) 73.34 percent, *A. indica* (15g/kg) 70.67 percent, *Z. armatum* (10g/kg) 70.34 percent, *and Z. officinale* (20g/kg) 58.34 percent. Similarly lowest percent weight loss (3.32 percent) and damage of seed (4.0 percent) were observed in wheat treated with *A. calamus* (Khanal *et al*. 2021) [10]. Indigenous products such as plant products, animal-derived products and inert materials treated @ 2g/100g of wheat grains against rice weevil, *Sitophilus oryzae* on stored wheat. The minimum number of adults weevils of *S. oryzae* (4.00, 6.00,7.67, 9.00, 9.67 and 10.33) have emerged in wheat grains treated with ash powder, sand, cow dung powder, talcum powder, ajwain seed powder and neem leaf powder, respectively, with minimum grain damage (7.33 percent, 8.67 percent, 11.67 percent and 12.00 percent) was observed on ash powder, sand, ajwain seed powder and talcum powder, respectively, whereas minimum weight loss (2.67 percent, 3.67 percent, 5.67 percent and 6.67 percent) was recorded on ash powder, sand, cow dung powder, talcum powder and ajwain seed powder, respectively After 180 days of treatments (Yadav and Tiwari, 2017; Dash *et al*. 2021) [29, 9].

b. Nano Formulations

Three nano formulations evaluated against *S. oryzae* in maize grains are nano silica, nano alumina and nano clay at three different dosages were used @ 500, 250, 125 ppm kg^{-1}. Nano silica @ 250 and 125 ppm kg^{-1} which caused cent percent mortality at three days after treatment. Nano silica at 500, 250 and 125 ppm kg^{-1} inhibited oviposition and no adult emergence of *S. oryzae* was observed and has a great promise in pest management (Padmasri *et al*. 2018) [20].

c. Resistant Varieties

Varietal screening studies were carried out with 25 rice genotypes and performances of them were assessed based on various biological parameters, damage and infestation by *Sitophilus oryzae*. Index of susceptibility (IS) was taken as criteria for assessing the resistance or susceptibility of selected genotypes to *S. oryzae*. As per the results obtained, none of the genotypes were found resistant to the weevil attack. However, eight genotypes with less IS *viz.*, JGL 3844 (2.53), MTU 1001 (3.16), RNR 2458 (3.21), JGL 1798 (3.26), MTU 1010 (3.29), MTU 7029 (3.37), KNM 118 (4.37) and RDR 7555 (4.64) were categorized as moderately resistant. While JGL 11118 (7.96) with high IS was found susceptible and the rest of genotypes were classified as moderately susceptible (Kiran *et al*. 2020; Tripathy *et al*. 2020) [2, 27].

d. IGRS

Ten adult rice weevils were exposed to three types of rice grains (long, medium and short) treated with buprofez in at 100, 200 and 300 ppm. Mortality was counted at 15, 21 and 28 days after treatment, while adult progeny was counted at 6, 7 and 8 weeks after buprofezin treatment to get a new generation. The data showed that buprofezin had no direct effect on the mortality of rice weevils regardless of the concentrations. Buprofezin at 300 ppm in rice grains significantly inhibited progeny production, while lower doses (200 and 100 ppm) had no significant effect but virtually reduces progeny number. Buprofezin caused decreasing progeny productivity by *S. oryzae* (L.) with increasing concentrations regardless of the types of rice grains (Das, 2013; Singh *et al*. 2017) [8, 25].

e. Biocontrol Agents

Combination of biocontrol agents and insecticide *B. bassiana* ARSEF 5500+M. anisopliae ARSEF 2974+3 ppm fenitrothion tested against the rice weevil gives 74.17 percent mortality (Dal Bello *et al*. 2011). Biological agents like pteromalids: *Anisoptero maluscalandrae* and *Lariophagus distinguendus*, used against rice weevil, *L. distinguendus* had the more significant effect, reducing weevil populations 98 percent followed by *A. calandrae* had given 79 percent mortality in unpolished rice (Eric and Jordi, 2002) [11].

Conclusion

It has been concluded that plant products like sweet flag rhizome powder, nanoformulation like nanosilica and biocontrol agents like *L. distinguendus* are effective in reducing *S.oryzae* (L) in cereal grains.

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