Plant Products in Controlling Rice Weevil *Sitophilus oryzae*

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Rice weevil *Sitophilus oryzae* causes severe damages to stored rice and other cereals. Traditionally, in our rural villages, plant products of neem and vitex have been used to protect stored grains. Many studies have been made to ascertain the efficacy of other plants and their parts, oils and extracts, in controlling rice weevil *Sitophilus oryzae*. This paper summarises the findings arrived at in various research studies with regard to the use of plant products in controlling rice weevil *Sitophilus oryzae*.

Introduction

*Rice Weevil and their Importance*

Stored product insect pests cause severe damage to food grains. *Sitophilus oryzae* is a common rice weevil and it is one of the most important storage pests, which causes severe damage to raw cereals throughout the world. Cotton has reported that one pair of *Sitophilus oryzae* can reproduce about one million of its species within a period of three months under favourable conditions. A larva of the *Sitophilus oryzae* consumes 14mg grain/d and in its adult stage consumes 0.4mg grain/d. While the quantity of grain consumed and the loss cumulatively is very high the quality of the grains remaining often the attack becomes very poor as the rice weevil reduces the nutritive value of the grains. Surveys conducted in the US and Canada indicated that 20-26 per cent of stored wheat was infested by storage pests. In India the damage of stored grains by insect pests was estimated as 6.5 per cent of the total storage. The above studies emphasise the need in controlling the rice weevil *Sitophilus oryzae*.

*Chemical Pesticides*

During the last few decades pests were controlled using chemical pesticides. Most of the farming community uses synthetic chemical pesticides readily available in the market. The indiscriminate use of chemical pesticides has led to the development of resistance. It has been found that about 500 species of insect pests are resistant to one or more pesticides. The application of chemical pesticides causes health hazards; Health authorities are constantly advocating reduction of chemical pesticides due to the presence of the chemical residues in grains. The chemical residues cause adverse effects on humans and on the environment. It is necessary to find out safe and eco-friendly pesticides in controlling storage pests.

*Importance of Plant Products in Controlling Storage Pests*

Plants, which have rich source of secondary metabolites, can act as insecticides, ovicides, ovipositional deterrents, feeding deterrents, and growth retardants. Most of the plant products are non-pollutant, less toxic and are easily biodegradable in nature. Certain plant powders are highly repellent and hence they can play a role in safe protection of stored grains. These powders can be used for small-scale storage by small and marginal farmers as follows:

(a) Powdered plant materials are admixed with surface layer of grain in storage or
(b) Stored grain is covered by crushed plant material, which exhibits a high degree of repellency or
(c) Plant powders are used to create repellent barrier around the grains in storage or
(d) Plant powders are used for packing materials.

Scientific investigations have been conducted to study the efficacy of plant products in controlling the rice weevil. The plant products that can be used in

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controlling the rice weevil and classified into three categories, namely:

(a) Plant oils,
(b) Plant leaves and powders, and
(c) Solvents extract and isolated compounds.

**Plant Oils and their Role on Grain Protection**

In India, application of vegetable oils to protect the seed has been a common cultural practice in rural villages. This application has now found favourable acceptance worldwide. Application of vegetable oils (3 mL/kg) such as castor (*Ricinus communis*), sesame, mustard, soya bean, *Eruca sativa* (*E. vesicaria*) and *Raphanus sativus* (Radish) has been found to be very effective; among the oils, radish oil is found to be more effective against *Sitophilus oryzae* and also increases the seed germination.

Sing et al.12 have studied naturally occurring essential oil from plant origin (1000 ppm in acetone) against *S. oryzae* and have reported that volatile oil from *Pinus longifolia* (*P. roxburghii*) reduces the rice weevil population by 37.51, 75.21 and 86.82 per cent after 30, 60, and 90d of application, respectively. The essential oils from *Arenga subulatum*, *Artemisia martins*, *Cedrus deodara*, Z. planispinum and *Pinus roxburghii* have protected wheat grains from the damage of rice weevil. The essential oils form *Callicarpa macrophylla* and *Zanthoxylum alatum* showed significant growth promotion of the pests. *Mentha citrata* (*M. piperita* var. *citrata*) oil fumigation is effective against *S. oryzae* for 30d. The essential oil vapours of Indian *Acorus calamus* rhizomes were toxic to *S. oryzae*. The toxic effects were dependent on the period of exposure13.

Wheat treated with 2 per cent *Mentha longifolia* subsp. *himalanus* essential oil caused 100 per cent mortality within 48h. The major constituents present in this oil are piperitone oxides (26.5 per cent), piperitenone oxide (58.9 per cent) and other 6-monoterpenoid hydrocarbons (6.7 per cent) and four oxygenated monoterpenoids (5.9 per cent)14. Newly laid eggs exposed to 1 μL of *Acorus calamus* oil fumigation for 72h showed good controlling effect of the pest15. Essential oil of *Chenopodium ambrosioides* caused 52.5 per cent mortality at 50μg/insect16.

The number of off springs of *S. oryzae* emerging from food was considerably lower after it was treated with *Acorus calamus* oil vapours17. Suge oil at a concentration of 15μL/L caused 100 per cent mortality to *S. oryzae*18. The treatment with Mustard oil at 4 or 8mL/kg and 2 or 4 per cent concentration of turmeric powder gave appreciable mortality after 3-month storage period. The 4mL/kg of mustard oil combining 1-20g of turmeric powder/kg of rice gave best protection as it completely suppressed the progeny19. Treatment of maize with cottonseed, sesame, peanut, and paraffin oils increased adult mortality and reduced the production of off springs of *S. oryzae*. Higher concentration of these oils in treatment caused reduction in seed germination20.

Mustard, groundnut, sesame, maize, and neem oil and piperonyl butoxide showed synergistic or additive effect with five different insecticides, especially mustard oil, except for maize oil with permethrin against *S. oryzae*21. Weevil mortality was found to be maximum after 1d treatment of maize with mustard, soya bean, coconut, neem, groundnut, cotton, sesame or with castor. The percentage reduction in the average weevil population was highest in the case of soya bean oil at 3.30mL/kg, followed by cotton seed and coconut oils22. Sesame oil was a significant repellent while oat and wheat germ oils were attractive to *S. oryzae*. A commercial food product composed primarily of soya bean oil and wheat germ elicited no response from *S. oryzae*23.

Neem seed oil was the most effective against *S. oryzae*, followed by *Piper nigrum* seed powder, leaves of *Vitis negundo*, *Andrographis paniculata* dried mandarin fruit peel, rhizome powder of turmeric and seed powder of *Cassia fistula*, respectively24. Essential oil vapours of *Pimpinella anisum*, *Eucalyptus camaldulans*, *Thymbra spicata* var. *spicata* and *Satureja thymbra* caused over 94 per cent mortality with doses in the range of 108-135 μL/Litre25. *Mentha arvensis* (Japanese mint) oil was used effectively as a fumigant against *S. oryzae* in stored sorghum26 and the oil was recommended for sorghum seed preservation27. Essential oils from *Eucalyptus tereticornis*, *Eucalyptus citriodora*, *Citrus sinensis* and *Ocimum basilicum* were tested against *S. oryzae* in the laboratory in petri dishes. The test did not show any controlling effect28.

Synergistic effects were obtained in mixture of DDT with mustard, groundnut, sesame, maize, and neem oils or piperonyl butoxide, with lindane in combination with maize or neem oil piperonyl butoxide17. *Acorus calamus* oil was active against *S. oryzae* adults at 30°C but not at lower temperatures. The most active ingredient of the oil against *S. oryzae*...
was cis-asarone. The essential oil of *Caesalia axillaries* has the repellent activity.

**Plant Leaves and Powders in Controlling Rice Weevil**

The L50 values of sun dried leaves of guava and eucalyptus when admixed with rice grains, were 2.251 and 4.140g/100 of grains, respectively. Both test materials at 15g/100g depressed the phytophagy development of *S. oryzae*. Mentha spicata powder mixed with wheat grains at 2/100 wt/wt produced 100 per cent mortality and protected the grains for upto 4 weeks. Acorus calamus rhizome powder at 0.1 and 0.2 per cent mixed in milled rice, showed higher mortality after 3 or 6 months of storage and only a few progeny adults could emerge from 0.1 per cent concentration. The application of this powder for more than eight months had not affected the cooking quality of rice.

Application of powdered *Pachyrhizus erosus* at 2:100, 4:100 and 6:100 parts by weight of the powder to the wheat grains caused 83.33 - 96.66 per cent mortality and powdered *Polygonum hamiltonii* at 6:100 wt/wt caused 66.66 per cent mortality within 5 days. One gram of dried leaves of Ocimum cantum (Ocimum americanum) containing linalool at 8.6 ± 0.9 mg were tested and the LC50 value for *S. oryzae* was 427μg/cm2 (ref. 37). Seed powders of custard apple (*Annona squamosa*) and neem are found to be effective in controlling *S. oryzae*. Maize weevil was controlled by mixing small pieces of *Acorus calamus* rhizome with the grains stored in bamboo baskets.

In Nepal, locally available *Acorus calamus* rhizome was dried, powdered and applied at 50g/kg wheat. The results revealed that damage of stored grain was reduced from 33 per cent in untreated control to 5.4 per cent when treated. Damage by *S. oryzae* was reduced when the grain was admixed with powders or slurries (at 10 per cent) of seeds or leaves of Azadirachta indica or roots of Cissampelos quadrifoliata, seeds of *Datura stramonium* or Ricinus communis or leaves of *Chromolaena odorata*, *Ervthroplephm suaveolens*, *Sida acuta*, *Solanium nigrum* or *Hyptis spicigera*. Neem seed kernel powder at low dose (2 per cent w/w) was effective in protecting maize for 2 weeks, and dose of 10 per cent w/w was necessary for longer period of protection. Cotton stem ashes resulted in 65 per cent mortality in *S. oryzae* after three weeks of treatment.

At higher doses (1-5 per cent), powdered aerial parts of *Melilotus officinalis* (ribbed melilot) and *Melilotus albus* (white melilot) have repellent activity. Coumarin, a characteristic and volatile constituent of mililots, which produces the repellent effect. *Acorus calamus* collected from high altitude was slightly less toxic than from low altitude. Exposure to 2 per cent w/w admixed rhizome powder at 20°C, for 7 d resulted in complete adult mortality. Under field conditions at 20-30°C the initial residue of approximately 1300mg/kg of β-asarone content of rhizome powder is required to disinfest wheat containing these weevils. Azadirachta indica kernel powder at the rate of 10g/kg seed was the most effective protectant, the infestation percentage being 12.34 per cent as against 38 per cent in the untreated control.

Powdered aerial parts of lavender (*Lavandula angustifolia*), corn mint (*Mentha arvensis*) and horse mint (*Mentha longifolia*), and leaf powders of peppermint (*Mentha piperita*) and marjoram (*Origanum vulgare*) showed repellent activity against *S. oryzae*. Wheat grains mixed with 5 and 10 per cent air-dried Swallow root (*Decalepis hamiltonii*) caused 96 and 100 per cent mortality, respectively, and no progeny emerged from the treatment. The combination of neem and diatomaceous earth (1.0 g diatomaceous earth with 0.2 or 1.0g azadirachtin) was effective in controlling the pest population.

**Solvent Extract and Isolated Compounds from the Plants in Controlling Rice Weevil**

Nudiflorine, a pyridone alkaloid isolated from the leaves of *Trewia nudiflora* caused 90 and 76 per cent mortality after 12 h treatment at 1.25 and 1.0 per cent concentration respectively. Ground powder of fenugreek (*Trigonella foenumgraecum*) extract with chloroform was most toxic to *S. oryzae* followed by acetone, methanol and petroleum ether extracts. Based on the above, Afifi et al. have recommended that, fenugreek seeds be used as a dressing material at the rate of 500g/100 kg of flour or wheat grains.

Embelin (a benzoquinone isolated from the berries of *Embelia ribes*) and chloranil (quinone fungicide) applied at 0.0125 and 0.025 per cent (w/w) concentration, respectively in wheat produced 77.8 and 68.7 per cent mortality of *S. oryzae* after 14 d of exposure. Wheat grain surface treated with acetone extract of dill (*Anethum graveolens*) seeds at 2000 ppm reduced the F1 generation completely after 1d treatment. Rani and Jamil have reported that effect of petroleum ether extract of water hyacinth (*Eichhornia crassipes*) leaves to adults of *S. oryzae* was non-toxic. Aqueous or methylated spirit extract
of neem seed was more effective than neem leaf extract and it also seemed to control the emergence of *S. oryzae*.

Petroleum ether extracts of *Ricinus communis*, *Zanthoxylum badrunga*, and *Zanthoxylum alatum* (*Zanthoxylum planispinum*) showed antifeedant effect. Among the plant extract *Z. planispinum* appears to be the most effective. Fumigant of allylisoioxyanate, an allelochemical from cruciferous plants was tested against adult *S. oryzae* for LD$_{50}$ and LD$_{90}$ the resultant values were 0.482 and 10.582ng, respectively. The acetone extracts of *Dysophylla tomentosa*, *Hypis suaveolens*, *Lavendula perrottetii*, *Leucas stelligera*, *Ocimum americanum* *Pogostermon parviflorus* (aerial part), *Salvia plebia* (Essential oil) were coated on to the petridishes as a film of 200µg/cm$^2$. The study showed no adultcidal activity.

Sorbic acid (0.25 per cent) and a product of *Acorus calamus* (0.50 per cent) significantly reduced kernel infestation and F1 progeny production of weevils. Grain treated with chloroform extract of *Didymocarpus podocarpa*, petroleum ether extract *Coraria nepalensis* and *Clerodendron fragrans* showed antifeedant activity. The methanol extract of *Clerodendron siphononthus* appeared to be the most effective insecticidal chemical. Neem formulation containing crude extract from ripe berries of *Azadirachta indica* in 1 per cent concentration showed a mortality rate of 90 per cent.

The crude ethanol extract of *pithraj*, *Aphanamixis polystachya* (*Ricinocarpodendron polystachyum*) seed had strong repellent and feeding deterrent effects, and are moderately toxic. The ground leaf, bark and seeds in 2.5 per cent ratio, provide good protection for rice grains by reducing the F1 progeny emergence and the grain infestation. Powdered fruits of *Melia azedarach* reduced F1 progeny moderately and its acetone and petroleum ether extract showed high and complete reduction of F1 progeny. *Melia toosendan* bark extracts containing 675ppm toosendanin, after 6-week exposure exhibited 67 per cent mortality of *S. oryzae*. The extracts significantly reduced F1 adults.

Petroleum ether and methanol extracts of *Ricinus communis* (castor) seed gave a good protection of wheat grains for about 12 weeks than chloroform and acetone extracts. The LC$_{50}$ value of *S. oryzae* was exceeded after 24h with *Ocimum basilicum* (1 per cent), *Capsicum frutescens* (1 per cent), *Piper guineense* (0.2 per cent) and *Terepplerter* (1 per cent) and after 48h with *Eichhornia crassipere* (1 per cent). Petroleum ether extract of *Dicoma sesilifora* showed significant activity against adults and progeny development than *Neorautanenia mitis*.

Extracts of neem (*Azadirachta indica*) seed kernels in alcohol at 1.0 per cent concentration provide 100 per cent protection to rice grains for six weeks. Toxic effects were studied in acetone and petroleum ether extract and powders of *Capsicum frutescens* fruits and the leaves of *Clerodendron inerme*, *Eucalyptus globules* and *Dauranta plumeri*. In general petroleum ether and acetone (brought 100 per cent mortality) extracts were more effective than powders.

Insecticidal components against *S. oryzae* are isolated by chromatographic technique from sawdust of *Thujaopsis dolabrata*. The isolated component carvacrol showed some insecticidal activity and also fumigant action. The presence of sorghum tannin from *Sorghum bicolor* cultivars BKS5 in pellets significantly reduced the feeding activity of *S. oryzae*. RB-a (neem extract) did not act as an acute contact poison even at 1257μg/cm$^2$. It caused only 34 per cent mortality in *S. oryzae*. n-Hexane extract of *Eucalyptus tereticornis* leaves showed effect for up to four weeks.

*Tussilago farfara* (powdered leaves) and aerial parts of *Cichorium intybus* were attractive to weevils and can be used for sampling purposes. LC$_{50}$ of *Acorus calamus* extract (AC-Hex-1) on *S. oryzae* was reported to 3500μg/cm$^2$ (ref. 75). *Chenopodium multifidum*, *Flaveria bidentis*, *Aristolochia argentina* and *Tagetes erecta* showed a significant activity against *S. oryzae*. Thiosulphates isolated from *Allium plants* are found to be effective repellant against *S. oryzae*. The fraction extracted at 150-200°C from *Eupatorium adenophorum* (*E. trapezoides*) shows high level of insecticidal activity against *S. oryzae* and the LD$_{50}$ was found to be 15.5114mg/L.

**Conclusions**

In the present context of an ever-increasing population dwindling earthly resources it is very necessary to save food grains produced. The necessity to have non-toxic pesticides is gaining importance now-a-days. Most of the work in producing the biopesticides are in the experimental stage in the laboratories; large scale concerted efforts are required for mass production of non-toxic pesticides. At
present only neem product is commercially available in the market. The admixing of the powder and oil seems to be a laborious process and the availability of the raw materials are far, few and difficult to procure. The documentation of organoleptic properties such as appearance, flavor, taste, texture, and the germination of treated seeds are needed for most of the tested plant materials. Many bioresources are yet to be exploited. The efforts in identification, isolation, and development of new products from the plants have to be doubled for the effective control of insect pests. The following items have to be worked out efficiently:

(a) To select the most appropriate biopesticides for use, take into consideration the efficiency of the products, cost-effectiveness and the climatic variations of each region in the country;
(b) To produce sufficient amount of plant products to commercially manufacture biopesticides;
(c) To create maximum awareness among the users the advantages of the bio-pesticides, their uses and commercial availability of the products.
(d) To create a central organization to do the following tasks:

(i) To upgrade the technologies in the efficient production of the biopesticides,
(ii) To educate the users the advantages of biopesticides and their availability,
(iii) To encourage the commercial manufacture of efficient biopesticides, and
(iv) To oversee the quality of the biopesticides produces and their proper distribution and sales to various regions in the country.

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