



Review Paper

A Review on efficacy of *Azadirachta indica* A. Juss based biopesticides: An Indian perspective

Mondal Debashri^{1*} and Mondal Tamal²

¹Dept. of Zoology, Raiganj Surendranath Mahavidyalaya, Raiganj, Uttar Dinajpur, West Bengal, INDIA

²Dept. of Botany, Netaji Mahavidyalaya, Arambagh, Hooghly, West Bengal, INDIA

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Abstract

Although both synthetic and natural of pesticides are used extensively in the agricultural fields to control crop pests, it is well known that natural pesticides are eco- friendly and are safe to the non target organisms. The *Azadirachta indica* A. Juss (neem tree), has long been recognized for its insecticidal properties. Nearly 550 insect pest species are sensitive to azadirachtin, an active compound extracted from the *A. indica* tree. Nowadays pesticides from *A. indica* become very much popular because of their biodegradability, least persistence and least toxic to non-target organisms, economic and easy availability. In India, neem products are effective against various pests of both crop fields as well as stored grains like rice, wheat, corn, legumes, potato, tomato, etc. This review put a light on the use and efficacy of *A. indica* based pesticides against various pests of both crop fields as well as stored grains of India.

Key Words: Neem, azadirachtin, bio-pesticide, insect pests.

Introduction

Nowadays, pesticides are being used extensively in the control of crop pests. Synthetic insecticides are used widely for the control of various insect pests because they can be applied whenever and wherever needed, economical and most important thing is the reliability of control method. Hence, the production and consumption of pesticides has greatly increased in recent years. The contribution of pesticides to increase agricultural production cannot be denied, but synthetic pesticides have also caused unprecedented ecological damage, also induced serious health hazard among workers during manufacture, formulation and field applications¹. To overcome the problems of synthetic chemical hazards, one of the best control measures is the use of plant origin products. The popularity of the plant products increasing day by day because of their biodegradability, least persistence and least toxic to non-target organisms, economic and easy availability. Today about 200 plants with insecticidal activities are known². Among the natural products, one of the most promising natural compound is Azadirachtin, an active compound extracted from the *Azadirachta indica* A. Juss (neem) tree (Family Meliaceae) (figure 1) whose antiviral, antifungal, antibacterial and insecticidal properties have been known for several years³. Azadirachtin is active in nearly 550 insect species⁴, mostly in orders Coleoptera (beetles and weevils); Dictyoptera (cockroaches and mantids); Diptera (flies); Heteroptera (true bugs); Homoptera (aphids, leaf hoppers, wasps, and ants); Isoptera (termites); Lepidoptera (moths and butterflies); Orthoptera (grasshoppers, katydids);

Siphonaptera (fleas); and Thysanoptera (thrips) (AgroForestryTree Database).

Reasons of using pesticides of *A. indica*

A. indica has certain distinct advantages over most of the other commercially used plants as natural pesticides. These trees typically grow in the tropical and subtropical parts of Asia, but nowadays they are also cultivated in other warm regions of the world because of their considerable climatic tolerance. This tree even thrives on waste and marginal lands. Unlike pyrethrum (which requires careful cultivation), it once established, becomes perennial. In India *A. indica* grows almost throughout the country. It is adapted to wide range of temperature between 0^o and 45^oC and altitude upto 1500m above mean sea level. It requires a minimum rainfall of 450mm for its survival. It is one among a few species which can grow well on calcareous soils with pH upto 8.5 even in the presence of hard pan at a soil depth of 1.5-2.0 m⁵.

Salako⁶, stated that the use of *A. indica* has obvious advantages, which include: i) it is relatively cheap and easily available; ii) its complex mixture of active ingredients which function differently on various parts of the insects life cycle and physiology makes it difficult for pests to develop resistance to it; iii) it is systemic, thereby protecting the plant from within. This has resulted in wheat, barley, rice, sugar cane, tomatoes, cotton etc being protected from damaging insects for up to ten (10) weeks; iv) it parades a wide spectrum of pesticidal activity. Insects controlled by *A. indica* include migratory

locust, army worms, whitefly and even head lice. and v) it is found to be safe to beneficial organisms such as earthworms. Khalid and Shad⁷ specifically reported that their toxic effect is normally of an ephemeral nature disappearing within 14 - 21 days.



Figure-1
A. A. indica tree

Chemical compositions of *A. indica*

In India, pioneering work on the isolation and identifications of *A. indica* constituents was initiated in 1942 and has continued in various parts of the world. Leaves have been shown to contain crude fibre (11-24%), carbohydrates (48-58%), crude protein (14-18%), fat (2.3-6.9%), ash (7.7-8.5%), calcium (0.8-2.4%) and phosphorus (0.13-0.24%), as well as a number of amino acids. Recently, a two dimensional TLC method has revealed the presence of carotenoids and other constituents in the leaves of *A. indica*. Its oil is rich in fatty acids and cake (the solid residue following expulsion of the oil) has a high sulfur content relative to other oil cakes. A number of sugars and polysaccharides have been identified in the gum and bark of *A. indica*. In addition to these general types of constituents, a number of novel compounds have isolated from most parts of the tree⁸.

All parts of the *A. indica* tree possess insecticidal activity but seed karnel is the most effective. It has a multitude of pesticidal active ingredients which are together called "triterpene" more specifically "limnoids". The four best limnoids compounds are: Azadirachtin, Salannin, Meliantriol, and Nimbin. Azadirachtin (C₃₅H₄₄O₁₆) itself is a group of compounds such as Azadirachtin A, B, C, D, E, F, G etc. Of these, azadirachtin-A (Aza A) is the most plentiful and biologically active one which has shown repellent, antifeedent and insecticidal activity against a number of insect pests and it is generally Aza A that is used for commercial insecticides⁹.

Effectiveness of *A. indica* against pests of crop fields of India

Rice: Some of the major insect pests of rice are rice earhead bug (*Leptocorisa acuta*), rice leaf folder (RLF) (*Cnaphalocrocis medinalis*) and white-backed planthopper (WBPH), *Sogatella furcifera*¹⁰. The various parts of *A. indica* tree have been used in various agricultural fields for their effective insecticidal properties. Against *L. acuta*, 3 per cent oil emulsion spray of *A. indica*, is found to protect developing rice grains¹¹. Similarly, 1 % of its oil spray on the rice plant reduced the incidences of leaf folder¹², whereas the cake (de-oiled) amendment in the soil @ 150 kg/ha and oil spray of *A. indica* at 10 days intervals were found to check the infestation of *C. medinalis*¹³. Kernel extract of *A. indica* was reported to show juvenile hormone mimic activity and inhibited larval development of *C. medinalis* after mixing with 0.16 % teepol¹⁴ and it was also found to reduce the population of WBPH, when sprayed on the rice crop¹⁵. Root soaking of rice seedlings with kernel extract of *A. indica* reduced the incidences of WBPH¹⁶, whereas its oil (1 %) spray using 7.5 kg/ha with teepol controlled the attack of *S. furcifera*¹⁷ and showed antifeedant activity to this plant hopper¹⁸. Similarly, 5 % of *A. indica* cake extract spray reduced emergence of WBPH¹⁹. The extract of *A. indica* and azadirachtin affects the biology of brown planthopper (BPH), *Nilaparvatha lugens* (Stal)²⁰.

Wheat, Sorghum and Corn: Oriental army worm, *Mythimna separata* is an important pest of wheat in the seedling stage. It is also found to be a serious pest of sorghum along with the spotted stem borer, *Chilo partellus*, head bugs, *Calocoris angustatus* and the Yellow sugarcane aphid, *Melanaphis sacchari*. According to Sharma *et al.*²¹, extracts of *A. indica* and custard apple kernels were effective against all of these pests.

Corn earworm, *Helicoverpa zea* is a major pest of corn. Reed and Reed²² achieved a reduction of more than 60 % of this corn borer by applying seed extract of *A. indica*.

Legumes: Gram pod borer (*Helicoverpa armigera*) is found to be major insect pest of chickpea and pigeonpea, whereas white grubs like *Anomala dimidiata*, *Holotrichia seticollis* and *H. longipennis*; cutworm (*Agrotis ipsilon*) and blister beetles (*Mylabris phalerata*) and *Epicauna mannerheimi* are main pests of soybean and other kharif crops grown in Kumaon hills. Hairy caterpillar (*Spilosoma obliqua*) is reported to be a major pest of soybean. Against *H. armigera*, kernel extracts (38.57%) and oil (5%) sprays of *A. indica* were found to be effective in reducing the populations of this pest in chickpea²³, whereas Nemidin-9, a *A. indica* - based formulation inhibited the development of this pest by 70% at 1000 mg/litre concentration spray application²⁴.

Vegetable Crops: Mustard aphid (*Aphis erysemi*) is found to be regular and major pest of vegetables and mustard in addition to its act as a vector for Yellow Mosaic Virus of blackgram. Cabbage aphid (*Brevicoryne brassicae*) is also reported as an

important pest of cabbage in hilly areas¹⁰. Losses due to mustard aphid (*Lipaphis erysimi*) could be minimized by spraying the leaf and kernel extracts of *A. indica* on mustard crop²⁵. 1.5% oil spray of *A. indica* showed 100 per cent mortality to this aphid²⁶. Against cabbage aphid, *Brevicoryne brassicae* 12 % leaf extract of *A. indica* and leaf extract of *Annona squamosa* were found to show strong anti-feedancy to this aphid, whereas 0.5 % *A. indica* oil spray on cauliflower showed repellency to *B.brassicae*²⁷. According to Ketkar²⁸, 5 % seed kernel extract of *A. indica* can be effective against aphid or leaf beetle of brinjal, white fly, jassid and fruit borer of okra, red pumpkin beetle (*Raphiclopalpa foveicollis*) of pumpkin, *Helicoverpa armigera* of tomato.

Potato: Some of the important insect pests of potato like potato tuber moths (*Phthorimaea operculella*, *Polyphagous defoliator*, *Henosepilachna vigintioctopunctata*) are known to cause considerable losses in potato cultivation in sub-hill and hill regions. Spray application of neemrich (a *A. indica* based formulation) protected the crop against this pest²⁹.

Effectiveness of *A. indica* against pests of stored crops of India

The derivatives of *A. indica* are often used to protect harvested grains kept in bags and stores in India³⁰. Successful control of a range of stored grain insect pest species has been reported³¹. Food grain losses in India during storage at the farm level approximate 10% of the production³². The use of *A. indica* can confer significant economic advantage and service to rural areas in tropical developing countries, if reliable recommendations can be made and given to farmers for the protection of stored commodities, especially food grains, animal feed, and seed, from insects. This approach requires on the spot production and field testing of *A. indica* -based grain protectants as well as revalidation of previous reports. Some of these are reviewed here with respect to rice, wheat, sorghum and corn, legumes and potato.

Rice: In warehouses, 1-2% powdered seed kernel of *A. indica* mixed with harvested rice significantly reduced insect pest infestations³³. Mixing *A. indica* leaves with harvested rice, treating storage bags with 2% *A. indica* extract, or putting dried *A. indica* leaves (20-30 cm thick) between the bags and storage floor achieved similar results³⁴.

Wheat, Sorghum and Corn: Wheat stored in jute bags treated with 5% aqueous seed extract or 20% extract of *A. indica* leaves was protected from insect damage for up to 6 months³⁵. In India, Jotwani and Sircar³⁶ were the first to demonstrate that powdered *A. indica* kernel when mixed with wheat seed at a proportion of 1-2 to 100 (wt/wt) parts satisfactorily protected against *S. oryzae*, *R. dominica*, and *Trogoderma granarium* for 270, 320, and 380 days, respectively. Rahim³⁷ found that an ethanolic kernel extract of *A. indica*, containing azadirachtin, at 75mg/ kg protected stored wheat against *R. dominica* for up to 48 weeks.

In warehouse trials, wheat grain treated with *A. indica* oil at a proportion of 8 ml to 1 kg grain, prior to storing for 8 months in gunny bags, had 50 to 70% less infestation by *S. oryzae*, *R. dominica*, *T. castaneum*, and *Cryptolestes* sp.³³. Application of *A. indica* oil at a low concentration of 0.1% (wt/wt) to wheat grain reduced egg laying by *Sitotroga cerealella* as effectively as a 5% malathion dust treatment³⁸.

In India, sorghum seed mixed with powdered kernel of *A. indica* in a proportion of 100 to ≥ 1.5 (wt/wt) remained protected from damage by *Sitophilus oryzae*³⁹. Corn seed soaked for 20 minutes in a 1% solution of *A. indica* oil extractive was resistant to attack by *S. oryzae*⁴⁰.

Legumes: According to Jotwani and Sircar⁴¹, in India, green gram, chick pea, cowpea, and pea could be protected from damage by the pulse beetles, *Callosobruchus* spp., for 8-11 months by mixing powdered *A. indica* kernel with grains at 1 or 2 to 100 parts. Whereas according to Yadav⁴², *A. indica* kernel protected the legumes against *C. chinensis* and *C. maculatus* and stopped the development of progeny even 12 months after *C. chinensis* was released on treated lentil seed. Likewise, chick pea and pigeon pea seeds remained undamaged up to 12 months after treatment with 2g *A. indica* kernel powder per 100 g seed. Application of 1 to 3 parts of *A. indica* oil per 100 parts of Bengal gram rendered complete protection against *C. chinensis* for at least 135 days, without impairing seed germination. Ketkar³³ tested the efficacy of *A. indica* kernel and oil for protecting bagged leguminous seeds (peas, Bengal gram, *Phaseolus*, and *Vigna* spp.) from pulse beetles during 8 months storage in warehouse trials conducted in Pune, India. He investigated that oil treatment of *A. indica* at 8 ml to 1 kg of grains reduced the infestation to almost zero in Bengal gram and *Phaseolus* (vs. 14% in untreated Bengal gram and 26% in untreated *Phaseolus*). He also observed that *A. indica* oil did not affect seed viability and unused seeds were fit for animal and even human consumption. Ali *et al.*⁴³ reported that the oil of *A. indica* at 1 ml/100 g seed killed all the pulse beetle grubs and adults, and no eggs were laid on treated seed. On cowpea and bambara groundnut, *A. indica* oil at 8 ml/kg seed not only reduced oviposition, but also killed larvae; the activity persisted more than 90 days on cowpea and for 180 days on bambara groundnuts⁴⁴. Green gram was completely protected against *Callosobruchus* spp. when soaked for 20 minutes in a 1% solution of *A. indica* oil extractive⁴⁰. In India *A. indica* oil was found to be highly suitable for cowpea preservation and well adapted to the life styles of subsistence farmers, as it was inexpensive and its application did not need any tools.

Potato: *A. indica* can also be applied in reducing damage due to the potato tuber moth, *Phthorimaea operculella*, during storage. In India, in simulated storage trials as well as in actual storage trials conducted in a warehouse, a 4 month protection was achieved against the pest when harvested potato and the covering material was sprayed with 5 and 10% 'enriched' seed extract of *A. indica*⁴⁵.

Constraints: *A. indica* -based pest control technology is constrained by a number of technical and socioeconomic factors. These constraints exist even in areas of India where *A. indica* -based pest control has been used traditionally. One important constraint is that farmers have insufficient data on product effectiveness under farm conditions to convince them of the benefits. Another is that the raw products are cumbersome to handle, making them less attractive than the more easily dispensed synthetic pesticides.

The quality of raw botanical materials may vary greatly and may not be reliable. In addition, extension workers often do not have information to provide guidelines on correct use and timing. Comprehensive economic analyses are needed (both at the farm- and macrolevels) so that governments and other institutions can formulate policies on *A. indica* use. The analyses should consider national needs, governmental support policy, and marketing structure⁴⁶.

Conclusion

The products of *A. indica* are cheap, easy to prepare, eco-friendly and low-cost alternatives to agrochemicals. The extracts of *A. indica* have been compared with commercial pesticides on various crop pests where they have been found to be efficacious, and equally or more cost effective⁴⁷. There is evidence to suggest, however, that *A. indica* is not being exploited to its full potential by farmers of south and south-east Asia⁴⁸. There appears to be a number of reasons for this, including a lack of knowledge surrounding *A. indica*'s role in crop protection. The demand for commercial products of *A. indica* is increasing both for local markets and export markets. The pesticides from *A. indica* are registered in the USA and, as the search for more environmentally benign pesticides continues, the demand from both the USA and Europe is likely to increase. Despite the setback to the traditional pest control uses of *A. indica* due to the advent and popularization of synthetic insecticides, new interest in the pest control potential of *A. indica* has grown worldwide since the past decade. However, if full benefits are to be achieved, then further patronage is needed from governments, policy makers, administrators, public and private organizations, national and international programs, and the donor community. Definitely, treatments of *A. indica*, comprising the use of leaves, seed/kernel powder, extracts, and even bioactive principles, cannot replace completely chemical pesticides used in crop fields and stored products preservation, but the amounts of pesticide needed could be reduced, thereby decreasing the pesticide load in food grains. The materials of *A. indica*, in spite of possessing broad-spectrum activity against pests, are generally not hazardous to beneficial organisms, such as predators and parasitoids, and, with proper timing and innovative methods of application, their use could be integrated in pest management. With increased interest in the biological control of pests, this aspect merits investigation and evaluation.

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References

1. Ansari B.A. and Kumar K., Cypermethrin toxicity Effect on the carbohydrate metabolism of the Indian catfish, *Heteropneustes fossilis*, *The Sci. Total Environ.*, **72**, 161-166 (1988)
2. Singh R., Singh B. and Verma R.A., Efficiency of different indigenous plant products as grain protectant against *Callosobruchus chinensis* Linn. on pea., *Indian J. Entomol.*, **63**, 179-181 (2001)
3. Harikrishnan R., Rani M.N. and Balasundaram C., Hematological and biochemical parameters in common carp, *Cyprinus carpio*, following treatment for *Aeromonas hydrophila* infection, *Aquacult.*, **221**, 41-50 (2003)
4. Anuradha A. and Annadurai R.S., Biochemical and molecular evidence of azadirachtin binding to insect actins, *Curr. Sci.*, **95** (2008)
5. Anon, The wonder of neem, *Far Eastern Agriculture*, July/August, 17-18 (1992)
6. Salako E.A., Plant protection for the resource-poor farmers. A keynote address at Nigerian Society for Plant Protection. 30th Annual conference. UNAAB, Abeokuta Sept. 1st-4th, 2002 (2002)
7. Khalid S. and Shad R.A., Potential advantage of recent allelochemical discoveries and agro ecosystems, *Prog. Farm.* **11**, 30-35 (2002)
8. Fulekar M.H., *Environmental Biotechnology*. Oxford and IBH Publishing Co. Pvt. Ltd. New Delhi (2005)
9. Barceloux D., *Medical Toxicology of Natural Substances*, John Wiley & Sons, Inc. (2008)
10. Garg D.K., Certain parasites and predators of crop pests in hilly regions of Uttar Pradesh, *J. of Appl. Zool. Res.*, **7**, 55-56 (1996)
11. Gupta S.P., Prakash A. and Rao J., Bio-pesticidal activity of certain plant products against rice earhead bug, *Leptocorisa acuta* Thunb, *J. of Appl. Zool. Res.*, **1**(2), 55-58 (1990)
12. Mohan K., Gopalan M. and Balasubramanian G., Studies on the effects of neem products and monocrotophos against major pests of rice and their safety to natural enemies. *Indian J. Plant Protec.*, **19**, 23-30 (1991)
13. Krishnaiah N.V. and Kalode M.B., Efficacy of selected botanicals against rice insect pests under green house and field conditions, *Indian J. of Plant Protec.*, **18**, 197-205 (1990)

14. Schmutterer H., Saxena R.C. and Heyde J., Von Der., Morphogenetic effects of some partially purified fractions and methanolic extracts of neem seeds on *Mythimna separate* Walk, *Cnaphlocrosis medialis* Guen. *Zeitschrift fur Agwandt. Entomol.*, **95**, 230-237 (1983)
15. David P.M.M., Effect of slow release nitrogen fertilizers and the foliar spray of neem products on rice pests, *Madras Agricult. J.*, **73**, 274-277 (1986)
16. Saxena R.C., Justo H.D. and Rueda, B.P., Neem seed bitters for management of plant hopper and leaf hopper pests of rice, *Mid-Term Appraisal Works on Botanical Pest Control in Rice Based Cropping systems*, 19 (1987)
17. Sontakke B.K., Field efficacy of insecticide alone and in combination with neem oil against insect pests and their predators in rice., *Indian J. Entomol.*, **55**, 260-266 (1993)
18. Saxena R.C., Epicnoc P.B., Tu C.W. and Puma B.C., Neem Chinaberry and custard apple: antifeedant and insecticidal effects of seed oils on leaf hopper and plant hopper pests of rice, *Proc. II. Intn. Neem Conf., Rauisch- Holzhausen Castle FRG*, 403-412 (1984)
19. Ramraju K. and Sundara Babu P.C., Effect of plant derivatives on brown plant hopper (BPH) and white backed plant hopper (WBPH) nymphs emergence in rice, *Internat. Rice Res. Newslett.*, **14**, 30 (1989)
20. Senthil Nathan S., Choi M.Y., Paik C.H., Seo H.Y., Kim J.D. and Kang S.M., The toxic effects of neem extract and azadiractin on the brown planthopper, *Nilaparvatha lugens* (Stal), *Chemosphere*, **67**, 80 –88 (2007)
21. Sharma H.C., Sankaram A.V.B., Nwanze K.F. and Singh P.P., Utilization of natural pesticides derived from neem and custard apple in integrated pest management, in *Azadirachta indica* A. Juss., oxford and IBH Pub. Co. Pvt. Ltd., New Delhi, India, 199-213 (1999)
22. Reed D.K. and Reed G.I., Control of vegetable insects with neem seed extracts. *Proc. Indian Acad. Sci.* **94**: 335-339 (1985)
23. Siddappaji C., Kumar A.R.V. and Gangadhar R., Evaluation of different insecticidal sprays against the chickpea borer, *Heliothis armigera* Hubn. *Pesticides*, **20**, 13-16 (1986)
24. Nelson S.J., Sundarababu P.C., Rajavel D.S., Srimannarayana G. and Geetanjali Y., Antifeedant and growth inhibiting effects of azadirachtin-rich neem fractions on *Sogatella furcifera* Horvath, *Spodoptera litura* Fabr. and *Helicoverpa armigera* Hubn, *World Neem Conference*, 10 (1993)
25. Atwal A.S. and Pajni H.R., Preliminary studies on the insecticidal properties of drupes of *Melia azadirachta* against caterpillars of *Pieris brassicae* Linn, *Indian J. Entomol.*, **26**, 221-227 (1964)
26. Mani A., Kumudanathan K. and Jagadish C.A., Relative efficacy of neem oil and endosulfan against insect pests of mustard. *Neem News Lett.*, **7**, 129-131 (1990)
27. Singh K. and Sharma P.L., Studies on anti-feedant and repellent qualities of neem against aphid, *Brevicornye brassicae* Linn. on cauliflower and cabbage, *Res. and Development Report*, **3**, 33- 35 (1986)
28. Ketkar C.M., Use of neem (*Azadirachta indica* A Juss) and its by products in organic farming, In: Kleeberg, H. and C. P.W., Zebitz (Ed.) *Practice Oriented Results on Use and Production of Neem - Ingredients and Pheromones*, Proceedings of the 9th Workshop; Hohensolms, Germany, March 13. – 15. 2000, 31-38 (2003)
29. Prakash A., Rao J. and Nandagopal V., Future of Botanical Pesticides in rice, wheat, pulses and vegetables pest management, *J. Biopesticds.*, **1**, 154 – 169 (2008)
30. Ketkar C.M., Use of tree-derived non-edible oils as surface protectants for stored legumes against *Callosobruchus maculatus* and *C. chinensis*. In: Schmutterer, H. and Ascher K.R.S. (Ed.). *Natural pesticides from the neem tree (Azadirachta indica* A. Juss) and other tropical plants, Proceedings of the Third International Neem Conference, 10- 15 Jul 1986, Nairobi, Kenya. Deutsche Gesellschaft fur Technische Zusammenarbeit (GTZ) GmbH., Eschborn, Germany 535-542 (1987)
31. Golob P., Webley D.J., The use of plants and minerals as traditional protectants of stored products, Report, Tropical Products Institute G138, England, 32 (1980)
32. Lal S., Saving grain after harvest, In: Kasturi, G. (Ed.) *The Hindu Survey of Indian Agriculture – 1988*, National Press, Madras, India, 246-248 (1988)
33. Ketkar C.M., Utilization of neem (*Azadirachta indica* Juss) and its bye-products, Directorate of Non-edible Oils & Soap Industry, Khadi & Village Industries Commission, Bombay, India, 234 (1976)
34. Muda A.R., Utilization of neem as a pest control agent for stored paddy, In: Proceedings of the 7th Asean Technology Seminar on Grain Post-Harvest Technology, ASEAN Crops Post-Harvest Programme and Asean Food Handling Bureau, Manila, Philippine, 117-178 (1984)
35. Jilani G. and Amir P., Economics of neem in reducing wheat storage losses: policy implications, Technical Bulletin 2. Southeast Asian Regional Center for Graduate Study and Research in Agriculture, College, Laguna, Philippines. 15 (1987)
36. Jotwani M.G. and Sircar P., Neem as a protectant against bruchid *Callosobruchus maculatus* (Fabricius) infesting some leguminous seeds. *Indian J. Entomol.*, **29**, 21-24 (1967)
37. Rahim M., Biological activity of azadirachtin-enriched neem kernel extracts against *Rhyzopertha dominica* (F.)

- (Coleoptera: Bostrichidae) in stored wheat, *J. Stored Prod. Res.*, **34**,123-128 (1997)
38. Verma S.P., Singh B. and Singh Y.P., Studies on the comparative efficacy of certain grain protectants against *Sitotroga cerealella* Oliver. *Bull. Grain Technol.*, **24**, 37-42 (1985)
39. Deshpande A.D., Neem as a protectant against storage pests, *M.Sc. thesis*, Indian Agric. Res. Inst., New Delhi, India, (1967)
40. Attri B.S. and Prasad G.R., Studies on the pesticide value of neem oil by-products. *Pestology*, **4**, 16-20 (1980)
41. Jotwani M.G. and Sircar P., Neem seed as a protectant against stored grain pests infesting wheat seed, *Indian J. Entomol.*, **27**, 199-202 (1965)
42. Yadav T.D., Studies on the insecticidal treatment against bruchids *Callosobruchus maculatus* (Fab.) and *C. chinensis* (Linn.) damaging stored leguminous seeds, *Ph.D. thesis*, Univ. of Agra, India (1973)
43. Ali S.I., Singh O.P. and Misra U.S., Effectiveness of plant oils against pulse beetle, *Callosobruchus chinensis* Linn. *Indian J. Entomol.*, **45**, 6-9 (1983)
44. Pereira J., The effectiveness of six vegetable oils as protectants of cowpeas and bambara groundnut against infestation by *Callosobruchus maculatus* (F.), *J. Stored Prod. Res.* **19**, 57-62 (1983)
45. Sharma R.N., Nagasampagi B.A., Bhosle A.S., Mulkarni, M.M. and Tungikar V.B., 'Neemrich': the concept of enriched fractions from neem for behavioral and physiological control of insects, In: Schmutterer, H. Ascher, K.R.S. (Ed.) Natural Pesticides from the Neem Tree (*Azadirachta indica* A. Juss) and Other Tropical Plants. *Proc. 2nd Int. Neem Conf.*, Rauischholzhausen, Germany, 1983, 115-128 (1984)
46. Radwanski, S. A., Multiple land utilization in the tropics: an integrated approach with proposals for an international neem tree research and development program. In: Schmutterer, H., K. R. S. Ascher, and H. Rembold (Ed.) Natural pesticides from the neem tree (*Azadirachta indica* A. Juss). Proceedings of the First International Neem Conference, 16-18 Jun 1980, Rottach-Egern, German Agency for Technical Cooperation (GTZ), Federal Republic of Germany, 267-278 (1982)
47. Shukla A., Pathak S.C. and Agrawal R.K., Efficacy and economics of some insecticides and plant products against the infestation of okra shoot and fruit borer, *Earis vittella* Fab. *Crop Res.*, **12**, 367-373 (1996)
48. Moser G., Status Report on Global Neem Usage. Pesticide Service Project, PN 86.2588.1. GTZ, Griesheim, Germany, 39 (1996)