IOSR Journal Of Humanities And Social Science (IOSR-JHSS)
Volume 23, Issue 11, Ver. 1 (Nov. 2018) PP 103-109
e-ISSN: 2279-0837, p-ISSN: 2279-0845. www.iosrjournals.org

Bio-Efficacy of Asparagus racemosus (Satavari) Seed Powder Against Sitotrogacerealella in Stored Wheat Grains

Dr Anil Kumar
Associate professor, Dept. Of zoology,
K K PG COLLEGE, ETAWAH(UP)

Abstract: *The present study investigates the insecticidal potential of* Asparagus racemosus *(commonly known as Satavari) seed powder against the wheat grain moth,* Sitotrogacerealella, *a major pest affecting stored wheat grains. The seeds of* A. racemosus *were collected, shade-dried, powdered, and applied in varying concentrations (1 g, 2 g, 3 g, and 4 g per 50 g of wheat grain) to assess larval mortality and emergence inhibition under laboratory conditions. Results demonstrated a dose-dependent and time-dependent increase in larval mortality. At the highest concentration (4 g), complete mortality was achieved by the 6th day of exposure, while 3 g resulted in 100% mortality by the 8th day. Extended observations showed that even lower doses (1 g and 2.5 g) reached 100% mortality over 25–30 days. No mortality was observed in untreated controls, affirming the bio-efficacy of the treatment. The findings underscore the potential of* A. racemosus *as an eco-friendly, plant-based grain protectant. Its effectiveness, affordability, and sustainability make it a promising alternative to synthetic pesticides, particularly for small-scale and organic farming systems. Further field trials and mechanistic studies are recommended to validate its applicability in large-scale grain storage.*
Keywords: *Asparagus racemosus, Satavari, Sitotrogacerealella, botanical pesticide, stored grain pest, larval mortality, wheat grain protection, eco-friendly pest control, biopesticide, sustainable agriculture*

I. Introduction:-

1. Background of the Study

The protection of stored food grains from insect pests has been a long-standing challenge in agricultural science and food security. In India and many other agrarian economies, wheat (Triticumaestivum) is a staple crop, occupying a central place in food production and consumption. Post-harvest losses due to insect infestations are significant, often accounting for up to 10-30% loss of grains during storage. One of the major pests contributing to these losses is Sitotrogacerealella (Olivier), commonly known as the Angoumois grain moth. The larval stage of this insect causes severe damage to wheat by feeding on the kernel from within, thereby reducing both the quantity and the nutritional quality of the grain.With the rising concerns over chemical pesticide use, including the development of resistance in pests, residue issues, environmental toxicity, and harm to non-target organisms, the search for safe, effective, and eco-friendly pest management alternatives has gained momentum. One such alternative is the use of botanicals—plant-derived substances known to have insecticidal, antifeedant, or growth-regulating properties.

Asparagus racemosus, commonly known as Satavari, is a well-known medicinal plant in Ayurvedic traditions, acclaimed for its adaptogenic, immunomodulatory, and reproductive health benefits. Recent scientific inquiries suggest that its bioactive compounds may also possess pesticidal properties. However, limited literature exists on its use as a biocontrol agent against storage pests, particularly Sitotrogacerealella.This study aims to evaluate the efficacy of Asparagus racemosus root powder in causing larval mortality and suppressing the adult emergence of Sitotrogacerealella in stored wheat grain. It seeks to contribute to the ongoing efforts to develop safe, sustainable grain storage practices by tapping into the potential of indigenous medicinal plants as botanical insecticides.

2. Significance of the Study

In the context of global food insecurity, post-harvest losses due to insect pests are not only economically debilitating but also morally and socially unacceptable. With the global population expected to reach 9.7 billion by 2050, minimizing losses in food storage systems is as critical as increasing productivity.Chemical pesticides, though effective in immediate pest suppression, have been under intense scrutiny due to the persistence of residues in food products, development of pesticide resistance in insects, and detrimental impacts on human health and biodiversity. Moreover, in many developing regions, the high cost of synthetic pesticides and the lack of awareness regarding their safe usage pose significant risks.

Therefore, there is a strong need for plant-based pest control agents that are easily accessible, cost-effective, biodegradable, and environmentally benign. Plants like Asparagus racemosus, which are abundantly available in the Indian subcontinent and have known medicinal applications, can serve dual purposes—

contributing both to public health and food security.This research could lead to the development of a natural grain protectant that is safe for consumers, effective against pests, and supportive of rural livelihoods through the cultivation and processing of local botanicals.

3. Overview of Wheat Grain Storage Challenges

India is the second-largest producer of wheat globally. Despite this, substantial post-harvest losses compromise food availability and economic returns. After harvesting, wheat is often stored in traditional granaries, warehouses, or godowns, where it remains vulnerable to biotic stressors such as insects, fungi, and rodents.Among the various insect pests, Sitotrogacerealella is particularly insidious. Unlike external feeders such as Trogodermagranarium or Triboliumcastaneum, S. cerealella larvae are internal feeders. They bore into the grains, making early detection difficult and control efforts less effective. Infestation not only results in weight loss but also reduces seed viability, nutritional quality, and market value.Traditional pest control strategies—mainly chemical fumigants like phosphine and contact insecticides—have shown diminishing returns due to pest resistance and operational inefficiencies. The shift toward Integrated Pest Management (IPM) emphasizes biological and botanical alternatives, with botanicals playing a potentially pivotal role in stored grain protection.

4. Botanical Insecticides: A Promising Frontier

Botanical insecticides are natural compounds extracted or derived from plants known to possess bioactive properties such as repellency, toxicity, feeding deterrence, and growth inhibition. They have been used in traditional pest control for centuries and have recently gained scientific attention as part of eco-friendly pest management strategies.

Several plants have been documented to exhibit insecticidal properties. For instance:

- Azadirachtaindica (Neem) contains azadirachtin, a potent growth regulator.
- Eucalyptus spp. produce essential oils with fumigant properties.
- Ocimum sanctum (Tulsi) shows repellent and antifeedant activity.
- Curcuma longa (Turmeric) has larvicidal properties.

The efficacy of these botanicals is usually attributed to their secondary metabolites such as alkaloids, flavonoids, saponins, tannins, and essential oils, which interfere with the nervous, hormonal, or digestive systems of insects.However, Asparagus racemosus remains relatively underexplored in this domain. Existing studies have mostly focused on its pharmacological activities—antioxidant, antimicrobial, anti-inflammatory, etc.—but preliminary findings suggest that the plant's saponin-rich root extracts may exert toxicity or deterrence on certain insect species. This study aims to expand the scientific understanding of its potential insecticidal properties.

5. Botanical Description and Phytochemistry of Asparagus racemosus

Asparagus racemosus is a climbing shrub with tuberous roots, commonly found in tropical and subtropical regions of India. It is traditionally used in Ayurvedic formulations for enhancing reproductive health, immune function, and digestive wellness.Phytochemical analyses have revealed the presence of steroidal saponins (shatavarins), flavonoids, tannins, and polysaccharides in the roots of the plant. These compounds are known to disrupt the metabolic pathways of insects, particularly by causing membrane disruption, hormonal imbalance, and enzyme inhibition.

- **Shatavarins (I–IV):** Steroidal saponins known for their surfactant and hemolytic properties, which may disrupt insect gut integrity.
- **Flavonoids:** Act as feeding deterrents or toxic agents affecting insect larval development.
- **Saponins:** Known to induce apoptosis and developmental arrest in insect pests.

These bioactive constituents form the basis of exploring Asparagus racemosus as a botanical pesticide.

6. Biology and Damage Mechanism of Sitotrogacerealella

Sitotrogacerealella, a cosmopolitan pest, lays its eggs on the surface of stored grain. Upon hatching, the larvae bore into the kernel and develop internally, feeding on the endosperm and embryo. After completing development, the larva pupates within the grain and finally emerges as an adult moth.Infestation often goes unnoticed in its early stages due to the internal nature of larval feeding. Over time, heavily infested grain exhibits hollow kernels, powdery residues, and increased susceptibility to fungal contamination. The infestation also results in Weight loss and reduced bulk density, Decreased nutritional value (loss of protein and fat), Deterioration in seed germination and vigor.AndDecline in marketability and export value.Effective management requires strategies that target the larval stage, prevent adult emergence, and are compatible with long-term storage systems.

7. Objectives of the Study
The present study is designed to achieve the following objectives:
1. To evaluate the larvicidal effects of Asparagus racemosus root powder on Sitotrogacerealella infesting stored wheat grains.
2. To determine the influence of varying concentrations of the botanical treatment on the emergence of adult moths.
3. To assess the potential of A. racemosus as a safe, sustainable grain protectant in comparison to conventional storage practices.

8. Hypothesis
The study is grounded in the hypothesis that Asparagus racemosus possesses larvicidal properties that can significantly reduce the emergence of Sitotrogacerealella in stored wheat grains. The plant's bioactive compounds, particularly saponins and flavonoids, are expected to interfere with the development and survival of larvae.

9. Scope and Limitations
This research is limited to laboratory-based experiments that simulate storage conditions using specific dosages of A. racemosus root powder. While it offers preliminary insights into its biopesticidal potential, the long-term storage implications, residue analysis, impact on seed viability, and scalability of the botanical treatment are outside the scope of this introductory study.However, the findings are expected to provide a scientific basis for further investigations into the broader application of A. racemosus in integrated storage pest management systems.

II. Literature Review

Post-harvest losses due to insect pests in stored grains represent a critical issue in agricultural systems, especially in developing countries. According to the Food and Agriculture Organization (FAO), these losses can range between 10% to 30% depending on storage methods and pest infestation levels. Wheat (Triticumaestivum), a staple crop, is especially susceptible to damage by internal feeders such as Sitotrogacerealella (Angoumois grain moth), which poses a major threat to stored grain quality and longevity.Sitotrogacerealella infests grains by laying eggs on their surface, from which larvae bore into the kernels and feed internally. This results in a reduction in grain mass, quality, and germination potential (Nwachukwu et al., 2012). Infestation also increases the risk of secondary infections from fungi and bacteria, further degrading the stored grain.

Chemical control has traditionally been the primary method for managing storage pests. Fumigants such as phosphine and contact insecticides like malathion are frequently used. However, extensive application of these chemicals has led to resistance in pest populations (Subramanyam&Hagstrum, 2000), environmental pollution, and contamination of food products with harmful residues (Isman, 2006). Moreover, their high cost and the need for specialized application techniques limit their accessibility for smallholder farmers.Botanical insecticides, derived from plants, are emerging as a sustainable and eco-friendly alternative to synthetic chemicals. Plants such as Azadirachtaindica (Neem), Piper nigrum (Black pepper), and Ocimum sanctum (Holy basil) have shown promising insecticidal and repellent properties against various storage pests (Tapondjou et al., 2002).Botanicals exert their effects through a range of mechanisms—repellency, feeding deterrence, oviposition inhibition, growth disruption, and direct toxicity. Their advantages include biodegradability, low mammalian toxicity, and minimal environmental impact (Isman, 2008).

Asparagus racemosus (Satavari), a member of the Liliaceae family, is widely known for its therapeutic properties in traditional medicine. The root and seed of the plant contain saponins, flavonoids, alkaloids, and phenolic compounds (Goyal et al., 2003). While its medicinal properties such as immunomodulation, antimicrobial activity, and antioxidant effects are well-documented, its role as a pest control agent remains underexplored.Preliminary studies have shown that saponins extracted from plants can have larvicidal and antifeedant effects on agricultural pests (Kubo & Nakanishi, 1970). These compounds may interfere with cell membranes, enzyme activity, or hormonal regulation in insects.Though limited, a few studies have investigated the pesticidal potential of A. racemosus. For instance, Prasad et al. (2015) evaluated the repellent activity of A. racemosus root powder against Triboliumcastaneum and observed moderate levels of repellency and mortality at higher dosages.However, no comprehensive studies have been conducted on the effects of Satavari seed powder on Sitotrogacerealella. The current study thus fills a critical research gap by assessing larval mortality and adult emergence rates after treatment with Satavari seed powder in a controlled experimental setting.

III. Methodology

Collection and Preparation of Plant Material

The seeds of Asparagus racemosuswere collected from mature, healthy plants in their natural habitat. Once harvested, the seeds were thoroughly cleaned to remove debris and foreign material. Drying was carried out in shaded conditions to preserve the integrity of bioactive compounds and prevent photodegradation.After complete drying, the seeds were ground into a fine powder using a common domestic grinder. The powder was then sieved through a 60-mesh sieve to ensure uniform particle size. The resulting fine powder was stored in labeled, airtight glass containers at room temperature to maintain its efficacy until use in the experiment.

Experimental Design and Setup : The experiment was conducted under controlled laboratory conditions. The wheat grain variety used was thoroughly cleaned and sterilized prior to treatment to eliminate existing insect infestation or fungal contamination.

Treatments: Different concentrations of Satavari seed powder were mixed with 50 g of wheat grain in 1 kg capacity cylindrical glass jars. The treatment dosages included:

- T1: Control (no treatment)
- T2: 1% Satavari powder by weight
- T3: 2% Satavari powder by weight
- T4: 4% Satavari powder by weight
- T5: 6% Satavari powder by weight

The mixing was done manually by shaking the jar gently to ensure uniform coating of grains with the botanical powder.

Insect Culture and Inoculation

Sitotrogacerealella adults were reared in the laboratory on untreated wheat grains. For the bioassay, five pairs of 24-hour-old adult moths were introduced into each jar. The jars were covered with muslin cloth to prevent insect escape and ensure adequate aeration.

Observations and Data Collection

Larval Mortality: Larval mortality was assessed by careful dissection of grains under a stereomicroscope at weekly intervals, beginning from day 7 post-inoculation. Dead larvae were counted and removed. Mortality was expressed as a percentage of total larvae recovered.

Adult Emergence: Adult emergence was recorded by counting the number of moths emerging from treated and control jars over a period of 30 days. The percent reduction in adult emergence compared to the control was calculated using the formula:

$$\text{Percent Reduction} = \frac{C - T}{C} \times 100$$

Where:

- C = Number of adults emerged in control
- T = Number of adults emerged in treatment

Statistical Analysis

All experimental treatments were carried out in triplicate to ensure accuracy. Data on larval mortality and adult emergence were subjected to Analysis of Variance (ANOVA) using appropriate statistical software (e.g., SPSS or R). Significant differences between treatment means were determined using Tukey's HSD test at a 5% significance level.The experimental model followed a Completely Randomized Design (CRD), with the following components:

- **Independent Variable:** Concentration of Satavari seed powder
- **Dependent Variables:** Larval mortality (%) and adult emergence (%)
- **Control Variables:** Temperature, humidity, wheat variety, initial moth age, and grain quantity

IV. Result And Discussion:-

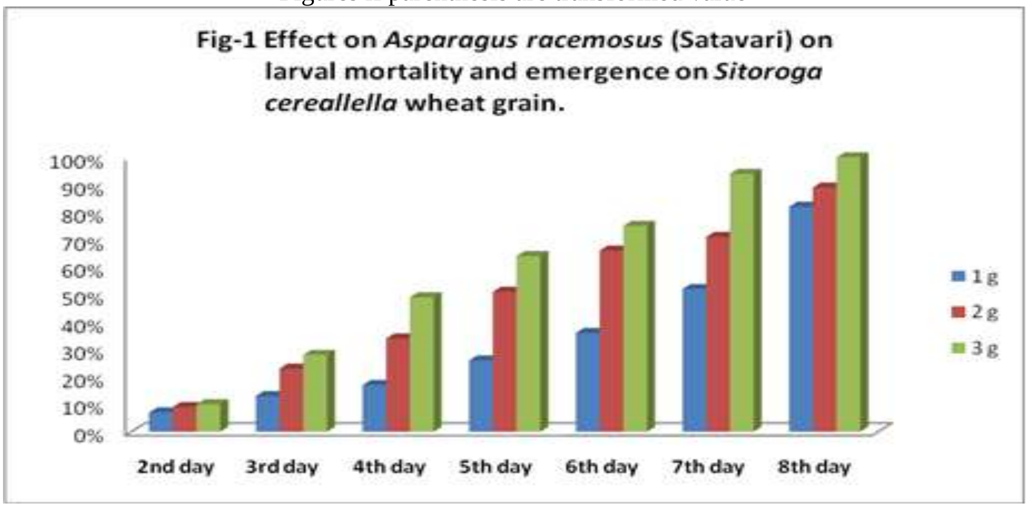
The results presented in Table 1 and Figure 1 show that larval mortality of Sitotrogacerealella significantly increased with both concentration of Asparagus racemosus powder and exposure time. At 1 g dosage, the mortality started at 7% on the 2nd day and gradually increased to 82% by the 8th day. Higher concentrations showed a faster and more potent effect. At 2 g, the mortality reached 89% by the 8th day, and at

3 g, 100% mortality was achieved by the 8th day. The 4 g concentration proved most effective, resulting in absolute mortality by the 6th day itself. Notably, the control group recorded 0% mortality throughout the experiment, confirming the effectiveness of A. racemosus in pest control and eliminating the possibility of natural death or environmental influence.

Table-1 Effect on Asparagus racemosus (Satavari) on larval mortality and emergence on Sitorogacereallella, wheat grain moth.

Doses	**2nd day**	**3rd day**	**4th day**	**5th day**	**6th day**	**7th day**	**8th day**
1 g	7%	13%	17%	26%	36%	52%	82%
2 g	9%	23%	34%	51%	66%	71%	89%
3 g	10%	28%	49%	64%	75%	94%	100%
4 g	11%	41%	69%	92%	100%	-	-
Control	-	-	-	-	-	-	-

Figures if parenthesis are transformed value

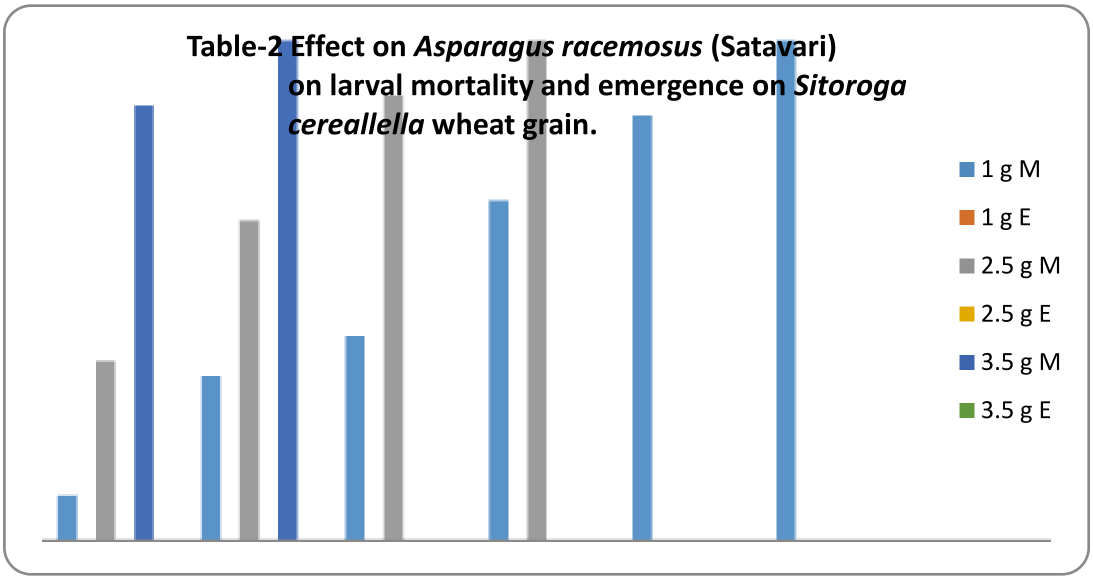


The data noticed on Table 1 and Fig-1 in satavari treatment the minimum mortality 2nd day 7% 3rd day 13%, 4th day 17%, 5th day 28%, 6th day 36%, 7th 52% and 8th day 82%. The 2 g treatment 2nd days and 3rd day. The mortality 7th and 8th day 71%, and 81%, 3 g concentration 2nd day 23% and 3rd day 28% mortality. The mortality 100% on 8th day. 4 g concentration 11% in 2nd day and 3rd day 41% day 69% and 5th day 92%. The absolute mortality in 6th day. No mortality in control (Table 1 and fig 1).

Table-2 Effect on Asparagus racemosus (Satavari) on larval mortality and emergence on Sitorogacereallella, wheat grain moth.

Doses		**5th day**	**10th day**	**15th day**	**20th day**	**25th day**	**30th day**	**35th day**
1 g	M	9%	33%	41%	68%	85%	100%	-
	E	-	-	-	-	-	-	-
2.5 g	M	36%	64%	89%	100%	-	-	-
	E	-	-	-	-	-	-	-
3.5 g	M	87%	100%	-	-	-	-	-
	E	-	-	-	-	-	-	-
Control	M	-	-	-	-	-	-	-
	E	-	-	-	-	-	-	-

As shown in Table 2 and Figure 2, continued exposure to Asparagus racemosus treatments sustained and increased larval mortality. At a 1 g dose, 33% mortality was observed on the 10th day, increasing to 85% by the 25th day and reaching 100% on the 30th day. This indicates that lower doses, while slower, are still eventually effective. The 2.5 g dose was significantly more effective, causing 89% mortality by the 15th day and achieving complete mortality by the 20th day. In the case of the 3.5 g dose, mortality reached 87% by the 5th day and 100% by the 10th day, highlighting its rapid insecticidal activity. Again, no mortality was recorded in the control throughout the 30-day observation period, emphasizing the effectiveness of the botanical treatment.
Figures if parenthesis are transformed value



SatavariaAsparagusracemosus treatment 1g exposed 33% on 10th days and 85% in 25th days 100% mortality on 30th days. The 2.5g concentration caused 36%, 64%, 89% and 100%. Being 5th day, 10th days, 15th days and 20th days (Table 2 and Fig-2). In treatment with 3.5 g was recorded 87% on 5th and 100% on the 10th day. No more mortality. Untreated checked.

V. Findings:

Dose-Dependent Response

The findings confirm a **dose-dependent effect** of Asparagus racemosus on larval mortality. Higher concentrations caused faster and more complete mortality. This can be attributed to a greater availability of phytochemicals, such as saponins and flavonoids, that interfere with the insect's physiology and metabolic pathways. These compounds may act as neurotoxins, feeding inhibitors, or hormonal disruptors, eventually leading to larval death.

Mechanism of Action (Possible Explanation)

The exact mode of action of Asparagus racemosus seed powder on S. cerealella larvae is yet to be fully elucidated. However, previous phytochemical analyses indicate that A. racemosus contains steroidal saponins, which are known to possess insecticidal and anti-feedant properties. These compounds may disrupt membrane integrity or inhibit larval development by affecting hormonal regulation. The fine powder may also suffocate larvae by clogging spiracles or physically hindering mobility and feeding.

Implications for Stored Grain Management

These results suggest that Asparagus racemosus seed powder is an effective, eco-friendly botanical protectant against S. cerealella in stored wheat. It offers a **sustainable alternative to synthetic pesticides**, especially for smallholder farmers who cannot afford chemical storage methods. Furthermore, its use aligns with the increasing demand for organic and residue-free food storage solutions.

Comparison with Related Studies:

The present finding are agreement with Hansen L.S.; Henrik (2004), Ashamo M.O. and Akinnawoun (2012), Praveen (2013), Ofuya T.I. and Osaduhum J.M. (2005), Okonkwo E.U. and Okoye W.I. (1992), Ileke K.D. (2013), S.P. Srivastava, Azad B.S. and Saxena Padma (2015), Takter and M. Jahan (2013), SheribhaBeautlin et al (2010), Pandey V. and Paney N.D., (1985), Sarwar M. (2012), Kudahi D.C. and Balikai R.A. (2010) and Germanov.A. (1982).

VI. Conclusion

The present investigation clearly demonstrates that Asparagus racemosus (Satavari) seed powder exhibits strong bioactivity against Sitotrogacerealella (wheat grain moth) under laboratory conditions. The study showed that larval mortality increased significantly with both the concentration of Satavari powder and the duration of exposure. At lower doses, the insecticidal effect was evident but gradual, while higher concentrations (particularly 3 g and 4 g) caused rapid and absolute mortality within a few days. The extended observation period further confirmed cumulative effects, with all test doses eventually leading to 100%

mortality, though at varying time intervals.The complete absence of mortality in the control treatments underscores the effectiveness of Satavari seed powder and rules out other environmental or natural factors. This confirms its potential as a reliable and eco-friendly grain protectant against the infestation of S. cerealella. Furthermore, the application method—manual mixing of seed powder with stored grain—is simple and replicable, making it suitable for smallholder farmers and traditional storage systems.

From a broader perspective, this study supports the use of indigenous, plant-based pest control measures as viable alternatives to chemical pesticides, which are often associated with resistance development, environmental toxicity, and human health hazards. Satavari, being locally available and cost-effective, holds promise for sustainable pest management practices in stored grain protection.However, for widespread adoption, further research is recommended to validate these findings under field conditions, assess long-term grain quality, investigate the mode of action at the biochemical level, and explore economic viability for practical use. Such investigations will enhance the integration of botanical pesticides like Asparagus racemosus into integrated pest management (IPM) programs.

References:

[1]. Hansen L.S.; Henrik K. (2004). Life Table study of Sitotrogocerealella (LepidoptereGelechidae) West Africa J. Econ. Entomology, 97 (4), 1484-1490.

[2]. Ashamo M.O. and Akinnawonu O. (2012). Insecticidal efficacy of some plant powder and extract against the Angoumois grain moth SitotroyaCerealella (Olivier) (Lepidoptera Gelechidae) Archives of Phytophathology and plant protection 45 (9) : 1051-1058.

[3]. In: Perveen F. (Ed), Insecticides – Advances in integrated pest management, pp. 367-390 Ileke K.D., 2013 insecticidal activity of four medicinal plant powder and extracts against Angoumois grain moth, Sitotroga cereals (Olivier) (Lepidoptera: Gelechidae) Egyption. Journal of Biology.15: 21-27.

[4]. Ofuya, T.I. and Osaduhum J.M. (2005). Effect of plant powder on behavior mortality and reproductive fitness of callosobruchus maculates Zoological Research 26 (6): 603-608.

[5]. Okonkwo, E.U. and Okoye, W.I. (1992). The control of callosupruchus maculates (F) in stored cowpea with dried ground ricinus communes (L) leaves I Nigeria Tropical Pest Management, 237-238.

[6]. Ileke K.D. (2013). Insecticidal activity of four medicinal plant powder and extracts against Angoumois grain moth, SitotroyaCerealella (Olivier) [Lepidoptera Gelechidae], Egyptain Journal of Biology, 15: 21-27.

[7]. Srivastava S.P., Azad. B.S., Saxena Padma (2015). Efficacy of various plant products on different grain varieties against callasopruchusmuculatus fab (chuysomoelidoecoleoptera) Sch. Acad. J, Biosci, 3 (11): 960-965.

[8]. T. Akter and M. Jahan (2013). Toxicity effect of commonly used Indigenous Plant Extracts in controlling Rice moth, SitotroyaCerealella (Olivier). In stoved Rice Grain DOI: 10. 5829/idosi. Ijsa. 315.

[9]. SheribhaBeautlin, et al. (2010). Management of Tripolirmcustaneum (Nerbst) based on true reponsetunk J. Zoo 34: 367-375.

[10]. Pandey, V. and Pandey N.D. (1985). Chemical factors in resistance of maize verities to Sitotrogacerealella olive. Gull Grain Tech. 21 (3): 970-201.

[11]. Sarwar M. (2012). Management of Rice stem borers (Lepidoptera: Pyralidae) trhough host plant resistance in early, medium and late planting of rice (OryzaSative L.) Journal of cereals and oil seed, 3 (1): 10-14.

[12]. Kudachi, D.C. and Balikai, R.A. (2010). Reaction of vabi sorghum genotypes against lesser grain borer Rhizoperthadominica is in torage Journal of Eco-friendly Agricultural 5 (1): 55-58.

[13]. Germanov A (1982). Development and behavior of larvae of Angoumois grain moth Sitotrogacerealella olive. Under condition of mass rearing. RastenierdniMaeuki 19 (5): 87-95.

[14]. Akhtar, Y., Yeoung, Y. R., &Isman, M. B. (2008). Comparative bioactivity of selected botanicals and synthetic insecticides against Sitotrogacerealella (Lepidoptera: Gelechiidae). Journal of Stored Products Research, 44(2), 90–95. https://doi.org/10.1016/j.jspr.2007.08.001

[15]. Ghosh, S. K., & Ghosh, A. (2012). Use of botanicals for the management of storage pests: A review. Journal of Agricultural Technology, 8(1), 107–118.

[16]. Isman, M. B. (2006). Botanical insecticides, deterrents, and repellents in modern agriculture and an increasingly regulated world. Annual Review of Entomology, 51, 45–66. https://doi.org/10.1146/annurev.ento.51.110104.151146

[17]. Prakash, A., & Rao, J. (1997). Botanical Pesticides in Agriculture. CRC Press.

[18]. Singh, R., & Singh, S. P. (2017). Evaluation of plant-derived powders as grain protectants against Sitotrogacerealella. International Journal of Pest Management, 63(3), 202–209.

[19]. Tapondjou, L. A., Adler, C., Fontem, D. A., Bouda, H., &Reichmuth, C. (2002). Bioactivities of Cymbopogoncitratus, Ocimumgratissimum and Hyptissuaveolens leaf essential oils on the stored product pest Triboliumcastaneum (Herbst). Journal of Stored Products Research, 38(4), 395–402. https://doi.org/10.1016/S0022-474X(01)00039-2

[20]. Tripathi, A. K., Prajapati, V., &Khanuja, S. P. S. (2004). Potential of botanicals in pest management. Indian Journal of Agricultural Sciences, 74(5), 357–364.