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Effectiveness of Agricultural Waste Ashes in Controlling *Sitophilus oryzae* Infestation in Stored Rice Grains

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

In this study, the insecticidal effectiveness of agricultural waste ashes of sawdust, rice husk, groundnut shell, maize cob, and wheat straw against *Sitophilus oryzae* in stored rice grains was investigated. The research, conducted to assess grain damage, weight loss, and weevil perforation index caused by *S. oryzae* over intervals of 30, 60 and 90 days. The ashes were applied at a rate of 2 gm per 100 gm of grains. Over a 90-day period the untreated control exhibited the highest grain damage (33.80%) and weight loss (14.23%). Among ash treatments, sawdust ash resulted in the highest grain damage (18.40%) and weight loss (12.47%), whereas groundnut shell ash was the most effective, showing the lowest grain damage (12.87%) and weight loss (8.53%). The chemical

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insecticide Chlorpyrifos 48EC maintained complete protection with 0% grain damage and weight loss. The Weevil Perforation Index (WPI) was significantly lower in groundnut shell ash (9.27) compared to other ash treatments, emphasizing its effectiveness in preserving rice quality.

Keywords: Agro-waste; entomotoxicity; Sitophilus oryzae; storage grain management; WPI.

1. INTRODUCTION

Rice (*Oryza sativa* L.) is a crucial staple food for over half of the global population, with approximately 90% of it being both produced and consumed in Asia [1,2]. It is a principal food crop in South and Southeastern countries, is the staple for over two-thirds of the Indian population, holding the key to food security and playing a pivotal role in the national economy [3]. Following China, India is the world's second-largest producer of rice [4]. It contributes 42% of total food grain production and 45% of total cereal production of the country [5]. Its cultivation plays a pivotal role in the economies, cultures, and diets of nations across the region. The crop's widespread cultivation is evidence to its critical role in sustaining livelihoods and ensuring food security. Previous research has demonstrated that rice varieties show differential susceptibility to stored product pests like *Sitophilus oryzae*, highlighting the importance of varietal selection in pest management strategies [6]. Understanding these varietal differences and their impact on storage conditions is crucial for developing effective pest management strategies. Proper storage techniques are essential to minimize post-harvest losses and ensure food security.

The primary focus of this study is to investigate eco-friendly alternatives for managing *Sitophilus oryzae* infestation in stored rice grains. *Sitophilus oryzae*, commonly known as the rice weevil, is a destructive pest capable of causing significant damage to stored rice grains. Its life cycle, encompassing both adult weevils and larvae, contributes to weight reduction and contamination of rice, posing economic threats to the rice industry [6]. It feeds on carbohydrates in rice, leading to weight loss and contamination of the stored grains [7,8]. The ability of *Sitophilus oryzae* to infest undamaged seeds exacerbates the issue, leading to grain heating, establishment of fungal colonies, and intrusion by secondary insect pests and mite pests, amplifying overall damage to stored rice [9]. Without effective control measures, stored grains face complete destruction.

The reliance on synthetic chemical pesticides, such as Chlorpyrifos 48 EC, for *Sitophilus oryzae* control raises environmental and health concerns, prompting the exploration of alternative, sustainable management strategies [10]. While Chlorpyrifos 48 EC is effective in controlling infestations, its potential for contamination of food intended for human consumption poses significant risks. The chemical management of stored-product pests poses significant risks due to the potential contamination of food intended for human consumption [11]. Traditional reliance on synthetic pesticides raises environmental concerns, prompting the need for eco-friendly solutions. Recent research highlights that agro-waste can be used effectively in pest management due to its chemical compositions and physical properties. Agro-waste ashes, with their abrasive nature, contribute to pest desiccation, while their chemical components can disrupt pest life cycles [13,14]. These materials offer a promising strategy for developing sustainable pest management practices. This research endeavors to comprehensively address the extent of *Sitophilus oryzae* infestation and investigate the entomotoxicity of selected agro-waste materials as eco-friendly alternatives. The systematic analysis of these issues aims to contribute valuable insights into the development of sustainable and effective strategies for *Sitophilus oryzae* management, providing potential alternatives to conventional synthetic chemical pesticides and decreasing post-harvest losses in stored rice.

Moreover, recent studies by Tadesse and Basedow [12] suggest that certain agricultural waste ashes possess toxic properties that can induce insect mortality. Additionally, the impact of rice husk ash on insect mortality may be linked to its high silica content, which is known for its insecticidal properties [13]. These studies underscore the potential of agricultural waste materials as eco-friendly alternatives for pest management.

This research aims to address the significant challenge posed by *Sitophilus oryzae* infestation in stored rice, exploring sustainable alternatives to synthetic chemical pesticides. The objective of this study aims to investigate the insecticidal effectiveness of selected agricultural waste ashes for controlling *Sitophilus oryzae* infestation in stored rice grains. By evaluating the impact of agricultural waste ash treatments on grain damage, weight loss, and weevil perforation index over 90 days, it provides insights into sustainable pest management practices for the management of *Sitophilus oryzae*.

By investigating the entomotoxicity of selected agricultural waste ashes and evaluating their efficacy in controlling *Sitophilus oryzae*, this study seeks to promote environmentally friendly practices in rice storage and enhance food security while minimizing the reliance on synthetic and chemical pesticides.

2. MATERIALS AND METHODS

2.1 Experimental Location

The study was carried out at the Research laboratory in the Department of Biological Sciences, SHUATS, Prayagraj, Uttar Pradesh under control conditions.

2.2 Insect Culture

Newly emerged 1-3 day old *Sitophilus oryzae* adults were used for this study. Adult *S. oryzae* were collected from already infested grains of rice. They were allowed to rear on local variety of medium grain rice in 5 plastic containers of 1kg capacity each. 100 pairs of adult insects were introduced to 1kg disinfected rice in each container. Opening of container was covered with a muslin cloth for proper aeration [14]. Containers were kept at constant temperature of 27ºC and relative humidity of 65± 5 per cent for emergence of the adults.

2.3 Collection of Agro Waste

The samples viz., sawdust, rice husk, groundnut shell, maize cob and wheat straw were collected from local farmers and vendors. Chlorpyrifos 48 EC was purchased from local shop.

2.4 Phytochemical Properties of Selected Agro-Waste

The above list 2 highlights the insecticidal compounds present in selected agricultural byproducts. These phytochemicals make agro-wastes valuable for sustainable pest management. Tannins and saponins in sawdust [15] have been shown to disrupt the digestive processes and cellular functions of insects. Flavonoids in rice husk [16] possess antioxidant properties that can impair the growth and reproduction of weevils. Groundnut shell contains saponins and alkaloids [17], which have both deterrent and toxic effects on pests, interfering with their feeding and physiological processes. Alkaloids and flavonoids in maize cob [18] contribute to its efficacy by acting as neurotoxins and disrupting hormonal balances in insects. Phytosterols and triterpenoids in wheat husk [19] can inhibit insect development and reproduction, providing a natural pest control solution. These phytochemicals collectively enhance the potential of agro-wastes in controlling weevil populations effectively.

List 1. Details of agro-wastes used

T. No.	Common name	Scientific name
T_1	Sawdust	-
T_2	Rice husk	*Oryza sativa* L.
T_3	Groundnut shell	*Arachis hypogaea*
T_4	Maize cob	*Zea mays* L.
T_5	Wheat straw	*Triticum aestivum*
T_6	Chlorpyrifos 48 EC	-
T_7	Control	-

List 2. Phytochemical properties of agro-wastes

Agro-waste	Name of phytochemical
Sawdust	Tannins and Saponins [15]
Rice husk	Flavonoids [16]
Groundnut shell	Saponins, alkaloids [17]
Maize cob	alkaloids, flavonoid [18]
Wheat husk	phytosterols and triterpenoids [19]

2.5 Preparation of Agro Wastes Ash

The collected agro-waste which was free from any insecticides was brought to the research laboratory of department of Biological Sciences, SHUATS, Uttar Pradesh, Prayagraj for subsequent processing. The agro-waste was firstly dried for several days. The ash of agro-wastes was obtained burning it completely and was used by thoroughly mixing it separately with 100g of rice grains in a jar at dosage 2 gm per 100 gm of grain for *S. oryzae.* Controls for each set of treatments consists of grain containing no agro waste ash and each treatment was replicated three times.

2.6 Entomological Bioassay

The required quantity of ash @ 2g/100g and 2% chlorpyrifos 48EC was mixed with sterilized rice seeds separately. The seeds were placed inside the polythene bags and gently shaken both vertically and horizontally to ensure that each grain had a light coating of agro-waste ash on it. Five pairs of newly emerged adult *S. oryzae* were introduced into the treated rice with agro-waste ash (sawdust, rice husk, groundnut shell, maize cob and wheat straw) in 500 ml plastic containers and replicated three times for each treatment. The containers were covered with perforated lids for proper aeration carefully.

2.7 Assessment of Seed Damage and Weight Loss

Data was collected at specific intervals i.e., 30 days, 60 days and 90 days after treatment (DAT). Per cent grain damage was recorded on the basis of number of healthy and damage grain.

$$\text{Per cent seed damage} = \frac{(W\mu \times Nd) - (Wd \times N\mu)}{W\mu \times (Nd + N\mu)} \times 100 \quad (1)$$

Whereas,
Wμ = weight of undamaged seeds
Nμ = number of undamaged seeds
Wd = weight of damaged seeds
Nd = number of damaged seeds

Reduction in weight of the rice grains after treatment was assessed as follows:

$$\text{Per cent Weight loss} = \frac{Initial\ weight - Final\ weight}{Initial\ weight} \times 100 \quad (2)$$

2.8 Assessment of Weevil Perforation Index (WPI)

In order to evaluate the extent of damage to rice grains, an assessment was conducted following the mortality of all adult insects involved in each trial. Samples comprising 50 grains were chosen randomly from both treated and untreated grains, and the count of insect-damaged grains was meticulously recorded. The Weevil Perforation Index (WPI) was subsequently calculated using the formula presented by Fatope *et al.,* [20] as referenced by Arannilewa *et al.,* [21].

$$\text{WPI} = \frac{percentage\ of\ treated\ grains\ perforated}{percentage\ of\ control\ grains\ perfoated + percentage\ grains\ perforated} \times 100 \quad (3)$$

2.9 Statistical Analysis

The data were subject to statistical analysis. The experiment was conducted using a Randomized block design (RBD).

Skeleton of ANOVA (Analysis of variance): Standard error (S.E.) and critical difference (C.D.) values are calculated by using the
following formula:

C.D = S.E (m) × (t) Error D.F. at 5%

$$\text{S.E(m)} = \frac{\sqrt{MSS^E}}{r}$$

$$\text{C.V\%} = \frac{Standard\ deviation}{Mean} \times 100$$

C.V= critical variance

Table 1. ANOVA table

Source of variation	*Degree of freedom*	*Sum of squares*	*Mean sum of squares*	*F₀*
Factor A (between groups)	*a-1*	$SSA = \sum_{i=1}^{a} n_i(\overline{y_i} - \overline{y}_{..})^2$	$MSA=\frac{SSA}{(a-1)}$	$\frac{MSA}{MSE}$
Factor B (between groups	*b-t*	$SSB = \sum_{j-1}^{b}. n_j(\overline{y}_j - \overline{y}_{..})^2$	$MSB=\frac{SSB}{(b-1)}$	$\frac{MSB}{MSE}$
Error (within groups)	*(a-1) (b-1)*	*SSE= SST-SSA-SSB*	$MSE=\frac{SSE}{(a-1)(b-)}$	
Total	*N-1*	$SST = \sum_{i=1}^{a}.\sum_{j=1}^{b}(\overline{y}_{ij} - \overline{y..})^2$		

Whereas,
t =Treatment
N = Total source of variation
SSA=Sum of Squares for Factor A
SSB= Sum of Squares for Factor B
SSE= Sum of Squares for Error
SST = Total Sum of Squares
MSA= Mean Sum of Squares for Factor A
MSB= Mean Sum of Squares for Factor B
MSE= Mean Sum of Squares for Error
F_0= Calculated F-value

3. RESULTS

3.1 Efficacy of Agro-Waste Ash Treatment on Per Cent Grain Damage Caused by *S. oryzae* in Stored rice Investigated at Different Time Intervals under Laboratory Conditions

The data presented in Table 3 and illustrated in Fig. 1 demonstrate the efficacy of selected agro-waste ash treatments on percent grain damage in treated rice over 30, 60, and 90 days.

30 Days after Treatment: Groundnut shell ash (T_3) demonstrated the least grain damage (1.20%), followed by rice husk ash (T_2) (2.6%), sawdust ash (T_1) (4.13%), maize cob ash (T_4) (4.20%), and wheat straw ash (T_5) (4.20%). The untreated control (T_7) exhibited the highest damage (13.40%).

60 Days after Treatment: The control group (T_7) had the highest grain damage (19.60%). Among ash treatments, wheat straw ash (T_5) showed the highest damage (12.73%), followed by maize cob ash (T_4) (11.87%), sawdust ash (T_1) (11.40%), rice husk ash (T_2) (9.87%), and groundnut shell ash (T_3) (5.07%). Chlorpyrifos 48EC (T_6) maintained a 0% damage rate. Significant differences were observed across treatments, with all ash treatments showing reduced damage compared to the control.

90 Days after Treatment: The untreated control group (T_7) exhibited the highest grain damage (33.80%). Among ash treatments, sawdust ash (T_1) showed the highest damage (18.40%), followed by maize cob ash (T_4) (18.27%), wheat straw ash (T_5) (17.13%), rice husk ash (T_2) (13.67%), and groundnut shell ash (T_3) (12.87%). Chlorpyrifos 48EC (T_6) maintained complete protection with 0% damage. Over 90 days, the control group had the highest mean grain damage (22.27%), while groundnut shell ash (T_3) had the lowest (6.38%). All ash treatments showed significant reductions in grain damage compared to the control, with groundnut shell ash (T_3) being the most effective.

3.2 Efficacy of agro-waste ash treatment on per cent weight loss caused by *S. oryzae* in stored rice investigated at different time intervals under laboratory conditions

The data presented in Table 3 and illustrated in Fig. 2 show the efficacy of selected agro-waste ash treatments on percent weight loss in treated rice over 30, 60, and 90 days. The treatments included sawdust ash (T_1), rice husk ash (T_2), groundnut shell ash (T_3), maize cob ash (T_4), wheat straw ash (T_5), chlorpyrifos 48EC (T_6), and an untreated control (T_7).

30 Days after Treatment: The untreated control group (T_7) exhibited a weight loss of 4.03%. Among ash treatments, rice husk ash (T_2) and groundnut shell ash (T_3) showed the lowest weight loss rates at 0.97% and 0.07%, respectively. Sawdust ash (T_1) showed a weight loss of 5.27%, maize cob ash (T_4) at 2.27%, and wheat straw ash (T_5) at 3.00%. Chlorpyrifos 48EC (T_6) maintained a 0% weight loss.

60 Days after Treatment: The control group (T_7) had a weight loss of 9.17%. Among ash treatments, maize cob ash (T_4) showed the highest weight loss at 8.57%, followed by wheat straw ash (T_5) at 8.43%, and sawdust ash (T_1) at 7.50%. Rice husk ash (T_2) and groundnut shell ash (T_3) showed lower weight losses at 5.53% and 3.40%, respectively. Chlorpyrifos 48EC (T_6) maintained a 0% weight loss.

90 Days after Treatment: The control group (T_7) exhibited the highest weight loss at 14.23%. Among ash treatments, maize cob ash (T_4) showed the highest weight loss at 13.33%, followed by wheat straw ash (T_5) at 13.03%, sawdust ash (T_1) at 12.47%, and rice husk ash (T_2) at 12.20%. Groundnut shell ash (T_3) had the lowest weight loss among the ash treatments at 8.53%. Chlorpyrifos 48EC (T_6) maintained a 0% weight loss.

Statistical analysis revealed significant differences in weight loss rates among treatments, with groundnut shell ash (T_3) showing the highest efficacy in reducing weight loss over the 90-day period. These findings highlight the potential of groundnut shell ash as an effective, eco-friendly treatment for preserving stored rice quality.

Table 2. Effect of agro-waste ashes on per cent grain damage caused by *S. oryzae* in stored rice under laboratory conditions

Treatments		Dosage (per 100 gm grain)	Per Cent Grain Damage			
			30 [1]DAT	60 DAT	90 DAT	Mean
T_1	Sawdust ash	2gm	4.13	11.40	18.40	11.31
T_2	Rice husk ash	2gm	2.60	9.87	13.67	8.71
T_3	Groundnut shell ash	2gm	1.20	5.07	12.87	6.38
T_4	Maize cob ash	2gm	4.20	11.87	18.27	11.45
T_5	Wheat straw ash	2gm	4.20	12.73	17.13	11.35
T_6	Chlorpyrifos 48EC	2 %	0	0	0	0
T_7	Control	-	13.40	19.60	33.80	22.27
Mean			4.96	11.76	19.02	
			Result	**S. Ed. (±)**	**C.D. at 5%**	
Due to days			**[2]S**	2.261	4.794	
Due to Treatment			**S**	2.443	5.178	

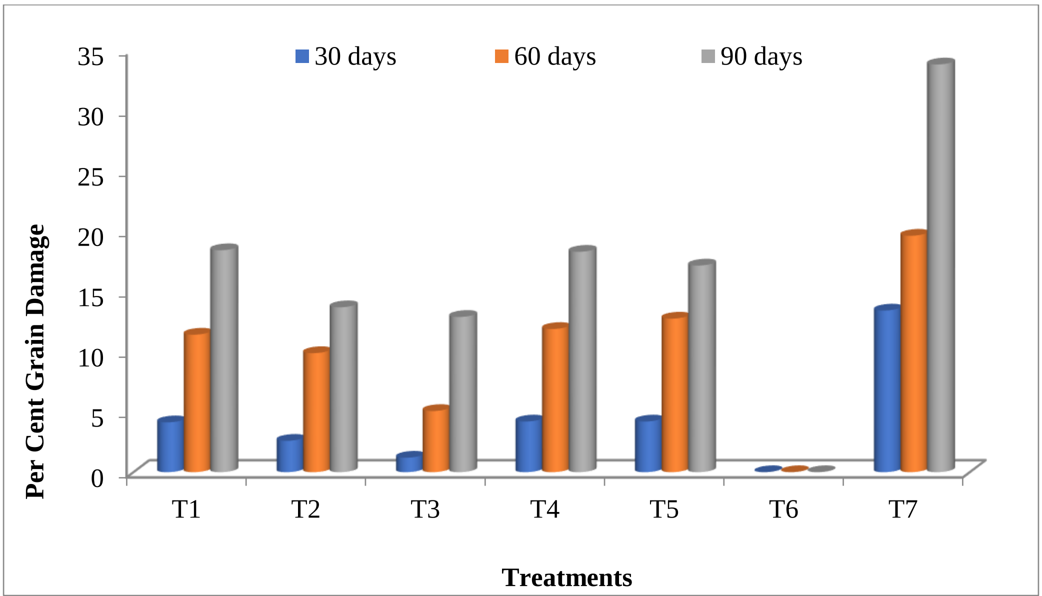

Fig. 1. **Effect of agro-waste ashes on per cent grain damage caused by *S. oryzae* in stored rice under laboratory conditions**

[1] *DAT: Days After Treatment*
[2] *Significant*

3.3 Weevil Perforation Index Caused by *S. oryzae* after Agro-Waste Ash Treatment in Stored Rice

The data provided in Table 4 and illustrated through Fig. 3 showed that the control treatment (T7) had the highest WPI at 50.00, showing substantial damage to the rice grains. In contrast, the chemical insecticide Chlorpyrifos 48EC (T6) maintained complete protection against weevil perforation with a WPI of 0.00.

Among the agro-waste ash treatments, the Groundnut shell ash (T_3) showed the lowest WPI at 9.27, indicating its effectiveness in protecting rice grains. This was followed by Rice husk ash (T_2) with a WPI of 11.13, and Sawdust ash (T_1) with a WPI of 12.73. Maize cob ash (T_4) and Wheat straw ash (T_5) exhibited higher WPI values of 14.47 and 14.97, respectively.

Table 3. Effect of agro-waste ashes on per cent weight loss caused by *S. oryzae* in stored rice under laboratory conditions

Treatments		Dosage (per100 gm grain)	Per cent weight loss			
			30 [3]DAT	60 DAT	90 DAT	Mean
T_1	Sawdust ash	2gm	5.27	7.50	12.47	8.41
T_2	Rice husk ash	2gm	0.97	5.53	12.20	6.23
T_3	Groundnut shell ash	2gm	0.07	3.40	8.53	4.00
T_4	Maize cob ash	2gm	2.27	8.57	13.33	8.06
T_5	Wheat straw ash	2gm	3.00	8.43	13.03	8.14
T_6	Chlorpyrifos 48EC	2%	0	0	0	0
T_7	Control	-	4.03	9.17	14.23	9.14
Mean			2.60	7.10	12.30	
			Result	S. Ed. (±)	C.D. at 5%	
Due to days			**[4]S**	1.176	2.493	
Due to Treatment			**S**	1.270	2.692	

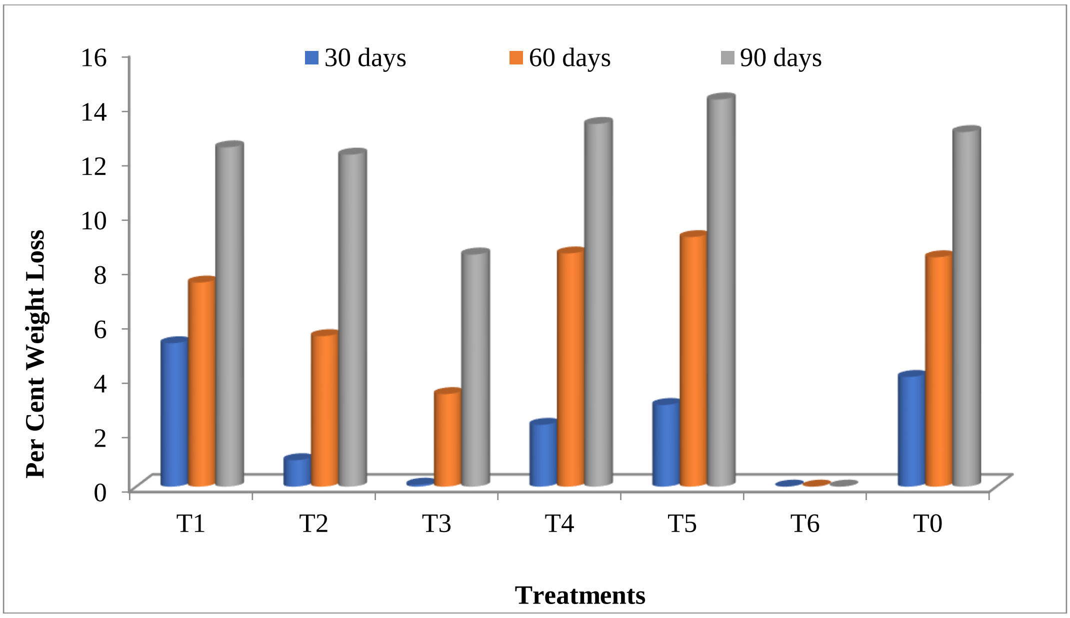

Fig. 2. Effect of agro-waste ash treatment on per cent weight loss caused by *S. oryzae* in treated rice

[3] *DAT: days after treatment*
[4] *Significant*

Table 4. Weevil Perforation Index caused by *S. oryzae* after ash treatment in stored rice

Treatments		**Dosage per 100gm of grains**	**WPI (weevil perforation index)**	
T_1	Sawdust ash	2gm	12.73	
T_2	Rice husk ash	2gm	11.13	
T_3	Groundnut shell ash	2gm	9.27	
T_4	Maize cob ash	2gm	14.47	
T_5	Wheat straw ash	2gm	14.97	
T_6	Chlorpyrifos 48EC	2%	0	
T_7	Control	-	50.00	
Mean			18.76	
		Result	**S. Ed. (±)**	**C.D. at 5%**
Due to replicate		**[5]S**	4.650	9.857
Treatments		**S**	5.022	10.647

[5] *Significant*

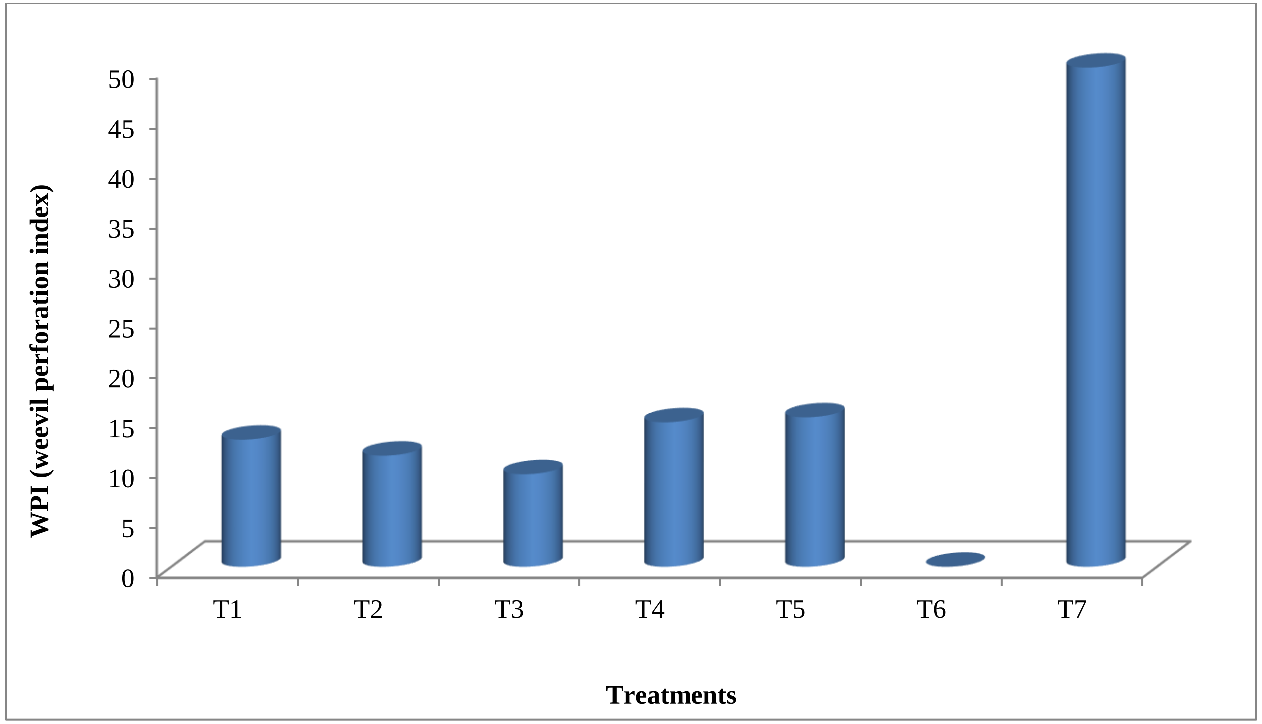

Fig. 3. Weevil Perforation Index caused by *S. oryzae* after treatment in stored rice

4. DISCUSSION

The findings of this study revealed that all five agricultural wastes exhibited insecticidal effectiveness. The results showed that the potency of the agricultural wastes varied with the duration of time after the treatment. Regardless of the dosage used, it was observed that groundnut shell ash caused more mortality of adult weevils (*Sitophilus oryzae*) than the remaining agro-wastes. All treatments were confirmed to exhibit variations in their effectiveness against the insect pest. The high efficacy of the agricultural wastes may have resulted from their ash's capacity to obstruct the beetles' spiracles, which would have caused asphyxiation [22,23]. The ash of the wastes may be due to its toxic properties causing desiccation of the insects' cuticle as suggested by Tadesse and Basedow [12]. Also, the impact of rice husk ash on mortality could be attributed to the high silica content in it. Silica has been documented for its insecticidal properties, which may have contributed to the effectiveness of rice husk ash in controlling *Sitophilus oryzae* infestation. The previous research by Akowuah *et al.,* [24] explored the efficacy of rice husk ash (RHA) as a grain protectant against various stored grain pests and this study aligns with our findings, indicating the insecticidal properties of agricultural by-products and their potential for pest management in stored grains. Rajeswari and Srinivasan [25] conducted a comprehensive study on the insecticidal properties of certain botanicals including rice husk ash against stored grain pests, including *Sitophilus oryzae*. They reported similar trends in mortality rates of adult weevils following treatment with rice husk ash, corroborating our observations.

Furthermore, a study by Inomisan and Sebastian [26] investigated the impact of groundnut shell ash on stored insect pests. Their findings align closely with our results, highlighting the superior performance of groundnut shell ash in protecting stored grains from *Sitophilus oryzae* infestation.

The results obtained from this research showed that sawdust, rice husk, groundnut shell, maize cob and wheat straw had distinct effects on the survival of *S. oryzae*. According to research, ash content has a negative effect on the mean weight loss and seed damage of the rice weevil. Ashamo and Ogungbite [27] suggested that the number of adult insects emerging from a safeguarded commodity directly proportional to the damage and weight loss experienced by said commodity. Remarkably, groundnut shell ash consistently demonstrated superior performance in minimizing both grain damage and weight loss throughout the experimental duration [28]. The decrease in seed damage and weight loss noted in this research could be linked to the diminished emergence of adult beetles.

In the context of the discussion, the Weevil Perforation Index (WPI) serves as a crucial parameter for evaluating the efficacy of agro-waste ash treatments against *Sitophilus oryzae* infestation. The WPI values provide insights into the ability of the treatments to mitigate weevil perforation in stored rice grains. Groundnut shell ash, applied at a dosage of 2 gm per 100 gm of grains, exhibited the most promising results with a WPI of 28.43%. This indicates a substantial reduction in weevil perforation, suggesting effective protection against infestation as compared to control with WPI of 58.9%. Typically, a WPI exceeding 50% signifies an exacerbation of infestation by the weevil or a negative impact of the tested material or insecticide on seed protection. Conversely, a WPI below 50% indicates a positive safeguarding effect of the treatment on the seeds [29]. In this study, the WPI values obtained for the agro-waste ash treatment indicate a significant deterrent effect on weevil perforation, thereby enhancing the protection of stored rice grains against *Sitophilus oryzae* infestation.

5. CONCLUSION

In conclusion, the findings of this study highlight the effectiveness of various agro-waste ashes in mitigating grain damage, weight loss, and weevil perforation caused by *Sitophilus oryzae* infestation in stored rice grains. Groundnut shell ash consistently demonstrated superior performance, exhibiting minimal grain damage and weight loss across all time intervals, along with a significantly low weevil perforation index. Rice husk ash also proved to be effective, particularly in reducing grain damage and weight loss. Maize cob ash, sawdust ash, and wheat straw ash exhibited varying degrees of effectiveness, with wheat straw ash showing the highest weight loss percentage after 90 days.

Overall, these results underscore the potential of agricultural waste ashes as eco-friendly alternatives for *Sitophilus oryzae* management in stored rice grains. Incorporating these materials into pest management strategies could help reduce post-harvest losses, promote food security, and mitigate environmental pollution. Further research is warranted to explore optimal dosages, application methods, and safety considerations of these agro-waste ashes, thus contributing to the development of sustainable and effective pest management practices in the rice industry.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declares that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of manuscripts.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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