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Protection of Stored Grain from *Callosobruchus maculatus* (F.) and *Sitophilus zeamais* (Mots.) Damage Using Rice Husk Ash from Locations

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Abstract

Rice husk ash (RHA) has previously been proven to be lethal to storage beetles. RHA obtained from six different Nigerian rice varieties were evaluated for their protective capability against grain damage by *Callosobruchus maculatus* Fabricius and *Sitophilus zeamais* Motschulsky under ambient laboratory conditions (28 ± 2ºC and relative humidity of 75 ± 5%) in Akure, Nigeria. Each ash was produced adopting standard methods, and evaluated at 0.0, 0.2, 0.4, 0.6, 0.8, and 1.0/ 20 g of grain dosages against 10 adults of each beetle species (5 males and 5 females). Whilst oviposition, adult emergence and seed damage was observed for *C. maculatus*, only adult emergence and seed damage was observed for *S. zeamais*, post infestation. All ash types generally significantly protected grain from damage by the two beetles in comparison with the unprotected control. Oviposition by *C. maculatus* was lowest in grain protected with RHA obtained from Jemila rice variety from Kaduna State, irrespective of rate of application. Irrespective of beetle species, Jemila RHA showed lowest adult emergence, seed damage and seed weight loss. Jemila RHA may be used to mitigate grain damage by seed beetles, and is recommended for consideration for combination with other non-chemical methods in integrated stored grain protection.

Keywords

Rice Husk Ash, *Callosobruchus maculatus*, *Sitophilus zeamais*, Grain, Damage

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1. Introduction

In traditional grain storage systems in many developing countries of the world, supposedly insecticidal plants are mixed with the grain by rural farmers to prevent insect infestation and damage [1, 2, 3]. Nevertheless, the use of synthetic chemical compounds dominates with respect to protection of grain harvested from crops cultivated purposely for cash. These synthetic chemicals, though very effective, have several drawbacks such as hazards to human health and the environment, development of insect resistance or tolerance to them, and their inconsistent supplies and prohibitive costs [4] which is restricting their use. Consequently, scientists in many developing countries have been investigating the potency of putatively insecticidal plants against storage insect pests with a view to obtaining replacements for the synthetics. Botanicals have been tested as whole or chopped parts, powders, ash, crude solvent extracts, vegetable oils, essential oils or more purified substances. Botanicals are generally thought to be cheaper, readily available, and more biodegradable, leading to less environmental problems [5, 3]. Plant ash is perhaps one of the commonest plant that is used to mitigate grain damage by insects during storage in African traditional systems. Ash from different plants species have been investigated and varying efficacies reported [6, 7, 3]. Rice husk ash appear to

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be particularly efficacious against storage beetle pest [8, 9, 10]. However, it is not known whether ash obtained from husk of different rice varieties have similar protective capability against grain damage by storage beetle pests. This paper presents results of an investigation of protection of stored grain against damage by the cowpea seed beetle, *Callosobruchus maculatus* F. and the maize weevil, *Sitophilus zeamais* Motschulsky, using husk ash obtained from six different Nigerian Rice varieties. *C. maculatus* and *S. zeamais* are probably the most destructive pests of cowpeas and maize, respectively, during storage in many tropical and subtropical countries of the world.

2. Materials and Methods

2.1. Insect Cultures, Cowpea and Maize Grain

The cultures of *C. maculatus* and *S. zeamais* were derived from cultures of these insects maintained at Institute of Agricultural Research and Training (IAR & T), Ibadan, Nigeria. The cultures were established and maintained in the Crop, Soil and Pest Management Research Laboratory, Obanla of The Federal University of Technology, Akure, Nigeria following the procedures described by [11] and [12], under ambient conditions of 28 ± 2°C and 75 ± 5% relative humidity. These cultures served as source of insects used in the study. Whilst *C. maculatus* was reared on Ife Brown cowpea, *S. zeamais* was reared on SUWAN-1 yellow maize obtained from IAR and T. Before use, the seeds were disinfested by deep freezing for two weeks and acclimated to ambient laboratory conditions.

2.2. Rice Husk and Ash

Rice husk (RH) of different rice varieties were obtained from rice mills in six different geographical locations in Nigeria: Lafiagi, Kwara State (Nupe rice variety); Dass, Bauchi State (Kilaki rice variety), Kachia, Kaduna State (Jemila rice variety); Omor, Anambra State (FARO 44 rice variety); Ogoja, Cross River State (Aroso rice variety) and Igbemo, Ekiti State (Igbemo rice variety).

Each RH was first pulverized in an electric blender into coarse powder. After pre-ashing by firing and cooling, it was transferred into a muffle furnace to produce rice husk ash (RHA) at temperature of 550°C for 12 hours [13]. The RHAs were kept separately in plastic containers with firm lids and stored in the laboratory until when needed.

2.3. Experimental Protocol

Twenty grams of clean grain (cowpea for *C. maculatus* and maize for *S. zeamais*), was separately weighed into 250 ml plastic containers to which was added a dosage of RHA and ten adult insects (unsexed with respect to *S. zeamais* but 5 males and 5 females of *C. maculatus*). The dosages of each RHA applied were 0.0, 0.2, 0.4, 0.6, 0.8 and 1.0 g, respectively. The 0.0 dosage constituted the control. All treatments were replicated thrice. The experimental design was a completely randomized design. For *C. maculatus*, 5days post infestation, all introduced insects were removed and number of eggs laid by the female beetles on the grain was counted and recorded. The treatments were observed for F1 adult emergence from 20days post infestation and the number found, recorded daily until no insects were found for five consecutive days from the day adult emergence started. The emerged insects were removed and the grain reweighed. The percentage adult emergence, seed damage, weight loss and percentage weevil perforation index (WPI) were calculated using the formulae below:

$$\%\ \text{Adult emergency} = \frac{\text{Number of emerged adult}}{\text{Total number of egg laid}} \times \frac{100}{1}$$

$$\%\ \text{Damaged seed} = \frac{\text{Number of seeds with holes}}{\text{Total number of seeds}} \times \frac{100}{1}$$

$$\%\ \text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1}$$

$$\%\ \text{WPI} = \frac{\%\ \text{treated cowpea seed perforated}}{\%\ \text{control cowpea seed perforated}} \times \frac{100}{1}$$

For *S. zeamais* all introduced adults were removed 5days post infestation and the treatments observed for F1 adult emergence from the 25th day post infestation until no insects were found for five consecutive days from when adult emergence began. The adults were then removed and the grain reweighed. The percentage adult inhibition rate (IR), and weight loss were calculated using the formulae below:

$$\%\ \text{IR} = \frac{\text{Number of insect in the treatment} - \text{number of insect in the control}}{\text{Number of insect in the control}} \times \frac{100}{1}$$

$$\%\ \text{weight loss} = \frac{\text{initial weight} - \text{final weight}}{\text{initial weight}} \times \frac{100}{1}$$

2.4. Data Analysis

Data were subjected to analysis of variance consistent with the completely randomized experimental design using SPSS version 17. Prior to analysis all data obtained by counts and percentages were square root and arcsine transformed, respectively. Significant means were separated using Tukey's Honestly Significant Difference Test at 5% level of significance.

3. Results

Irrespective of the dosage used, grain protected by the RHAs obtained from the six different geographical locations in Nigeria produced significant grain protection from damage by *C. maculatus* in comparison with the control, in terms of oviposition, percentage adult emergence, percentage weight loss, percentage seed damage and weevil perforation index (Figures 1-5).

The oviposition, percentage adult emergence, percentage seed damage and weight loss as well as the percentage WPI of the beetle varied significantly with ash type. Regardless of the dosage used, Jemila RHA produced lowest oviposition, adult emergence, seed weight loss, seed damage and weevil perforation index (WPI). Figure 1 showed that only grain protected with Jemila RHA had oviposition below 20 eggs at 0.2 g dosage and was significantly ($p< 0.05$) different from others. At the same dosage, Jemila RHA produced the lowest percentage of adult emergence, seed weight loss, seed damage and WPI of 0.50, 0.07, 1.16 and 3.41% respectively. At 0.4 g dosage none of the RHAs was able to prevent the oviposition, adult emergence as well as the seed weight loss, seed damage and WPI except Jemila RHA (Figure 2). All the RHAs were able to reduce adult emergence below 10% except Igbemo RHA from Ekiti State that recorded 17.68% adult emergence (Figure 3). At 0.8 g dosage, Jemila, FARO 44 and Kilaki RHAs from Kaduna, Anambra and Bauchi States, respectively, were able to produce seed weight loss and damage below 1% and were significantly ($p < 0.05$) different from other treatments (Figure 4). At 1.0 g dosage, all the RHAs were able to produce number of eggs fewer than 20 and they were all able to prevent adult emergence, seed weight loss and seed damage except Igbemo RHA from Ekiti State (Figure 5).

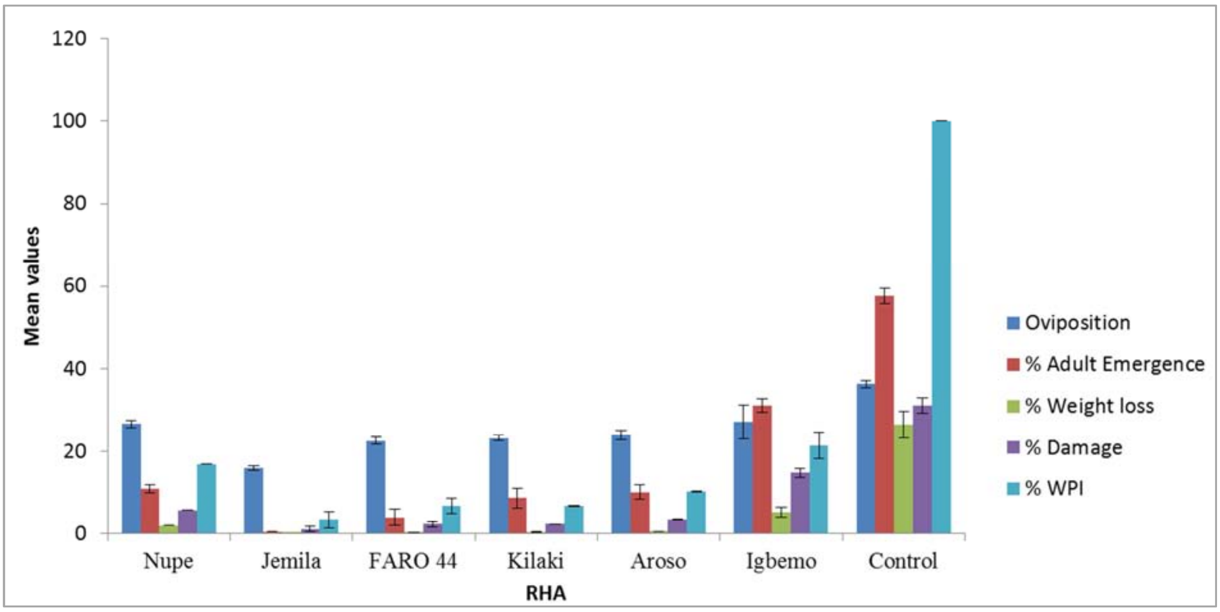

Figure 1. Protectability efficacy of rice husk ash from six different rice varieties in Nigeria against adult *C. maculatus* damage at 0.2 g/20 g of grain dosage.

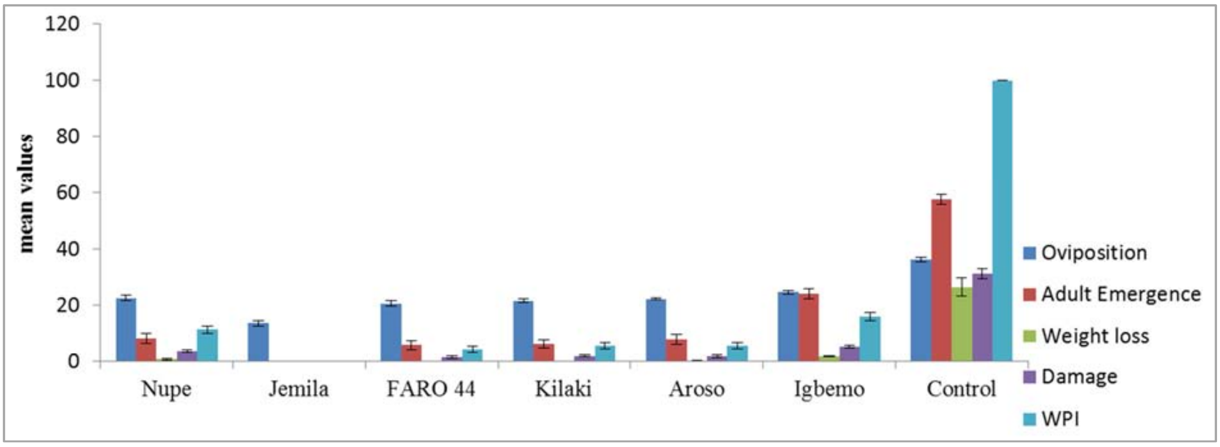

Figure 2. Protectability efficacy of rice husk ash from six different rice varieties in Nigeria against adult *C. maculatus* damage 0.4 g/ 20 g of grain dosage.

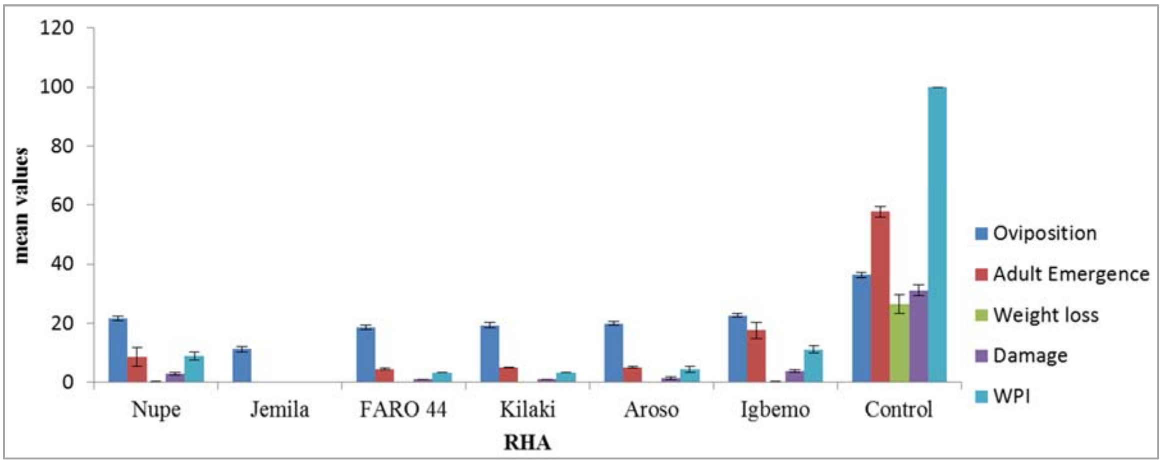

Figure 3. Protectability efficacy of rice husk ash from six different rice varieties in Nigeria against adult *C. maculatus* damage at 0.6 g/20 g of grain dosage.

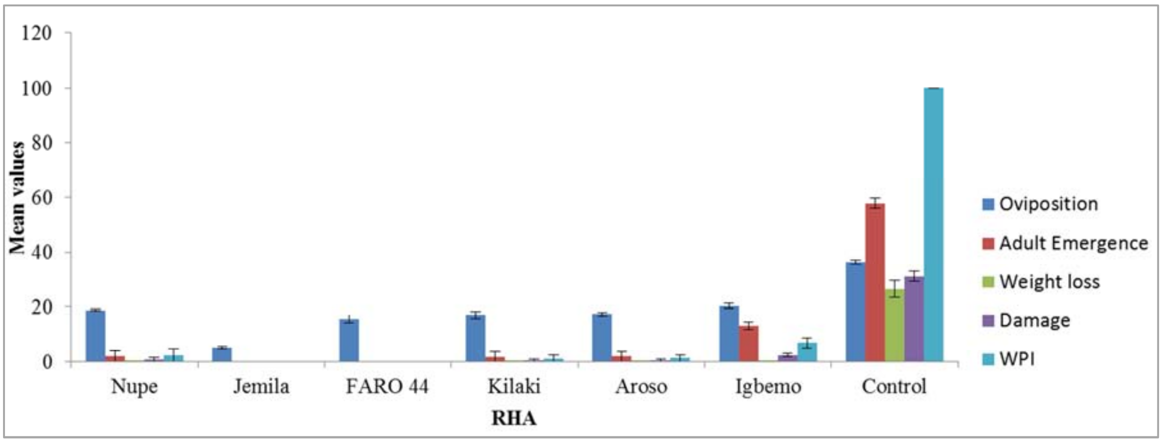

Figure 4. Protectability efficacy of rice husk ash from six different rice varieties in Nigeria against *C. maculatus* damage at 0.8 g/20 g of grain dosage.

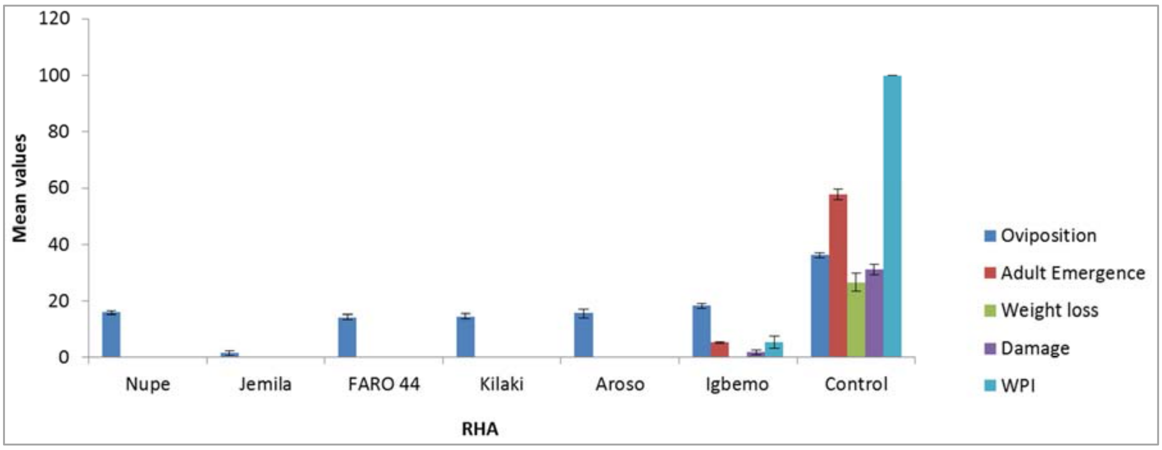

Figure 5. Protectability efficacy of rice husk ash from six different rice varieties in Nigeria against *C. maculatus* damage at 1.0 g/20 g of grain dosage.

F1 adult emergence of *S. zeamais* exposed to grain treated with different dosages of RHAs from different locations in Nigeria as well as the ability of the insect to cause seed weight loss, and adult inhibition rate (IR) are presented in Figures 6-10. The adult emergence and weight loss as well and IR varied significantly with the treatments and the dosage used. Significant differences ($p < 0.05$) existed between the treatments at all dosages and were significantly ($p < 0.05$) different from the control. Figure 6 showed that the Jemila RHA treated grain had the lowest number of F1 adult emergence and seed weight loss at 0.2 g dosage and was significantly ($p < 0.05$) different from others. At the same dosage, Jemila RHA inhibited the emergence of adult maize weevils to the tune of 98.67% and was significantly ($p < 0.05$) different from other treatments except FARO 44 and Kilaki RHAs. At 0.4 g dosage none of the RHAs was able to prevent F1 adult emergence as well as the seed weight loss except Jemila RHA which inhibited the emergence of F1 adult beetles completely (100%) but was not significantly ($p > 0.05$) different from FARO 44 RHA that recorded 0.67 number of F1 adults, 0.13% weight loss and 98.67% IR (Figure 7). F1 adult emergence and seed weight loss were recorded in all the RHAs except Jemila RHA that had zero F1 adult emergence, no weight loss and 100% IR at 0.6 g dosage (Figure 8). At 0.8 g dosage, there were no F1 adults emerging and no weight loss in maize treated with Jemila and FARO 44 RHAs and were significantly ($p < 0.05$) different from others except Kilaki RHA treatment that had 0.75, and 0.55%, respectively (Figure 9). All the RHAs at the 1.0 g dosage were able to prevent F1 adult emergence and seed weight loss except Nupe and Igbemo RHAs that recorded 0.33, and 0.07%, respectively (Figure 10).

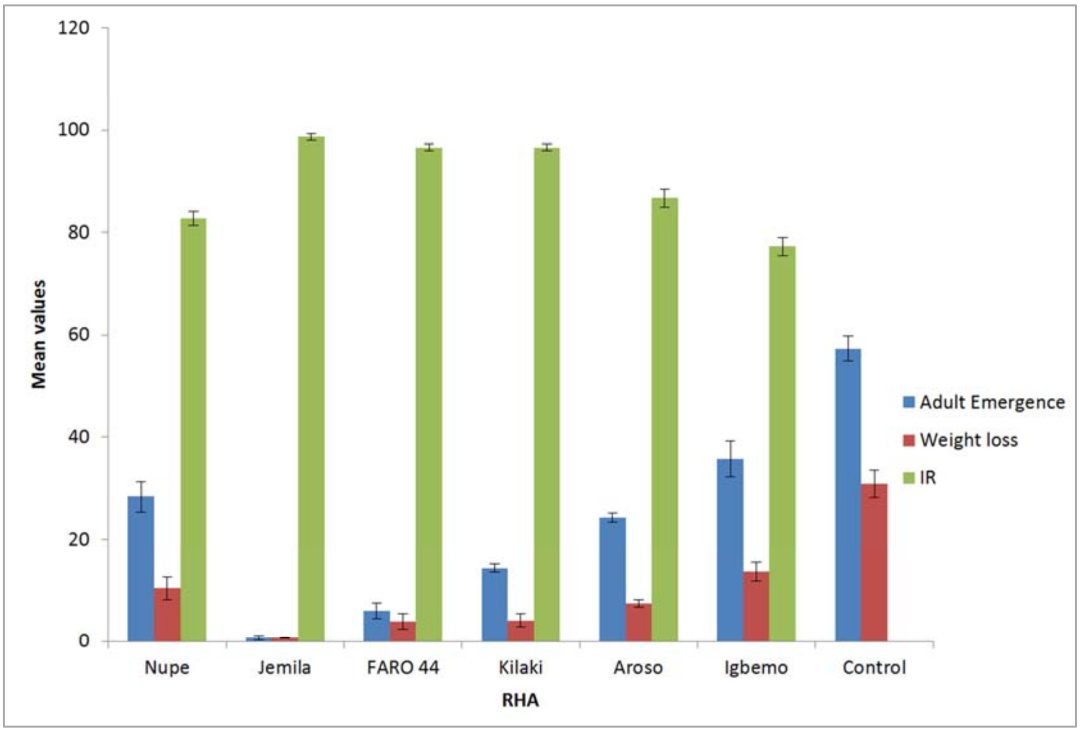

Figure 6. F1 adult emergence, IR and percentage weight loss in maize treated with 0.2 g dosage of different RHAs against *S. zeamais* damage.

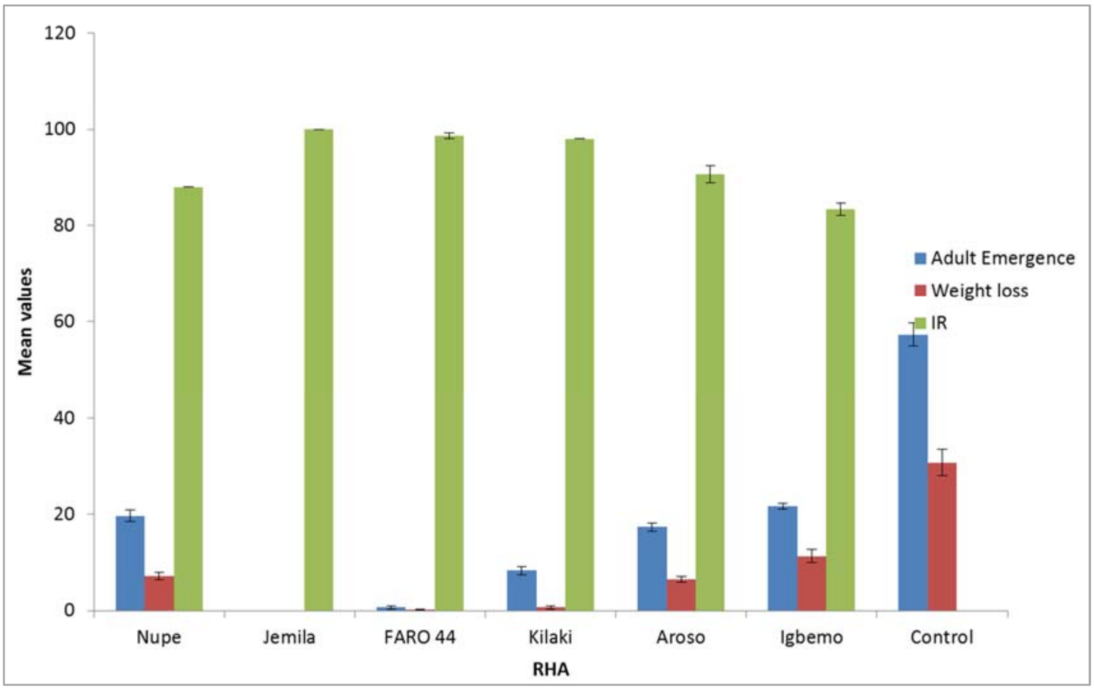

Figure 7. F1 adult emergence, IR and percentage weight loss in maize treated with 0.4 g dosage of different RHAs against *S. zeamais* damage.

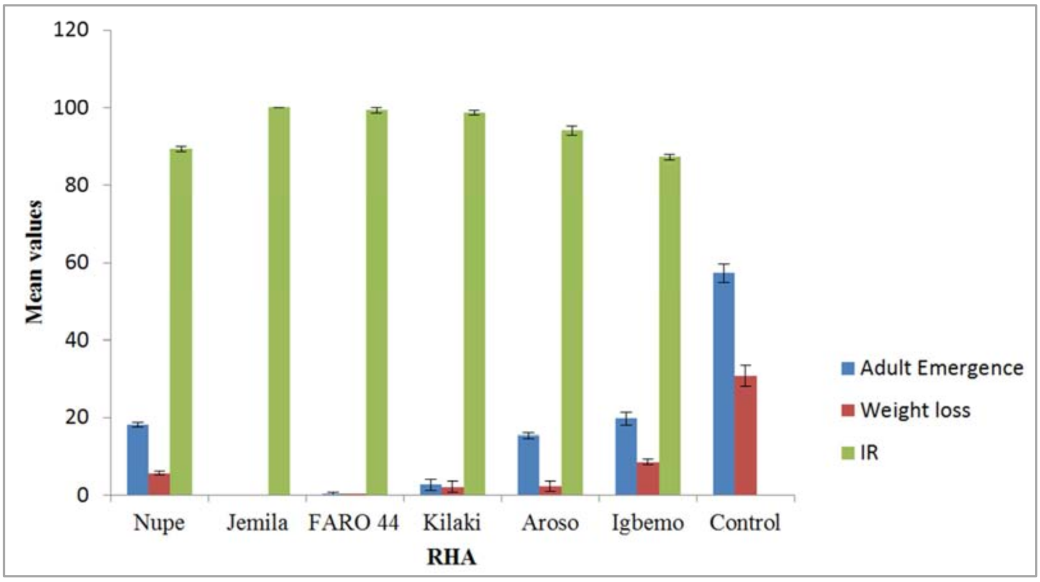

Figure 8. F1 adult emergence IR and percentage weight loss of maize treated with 0.6 g dosage of different RHAs against *S. zeamais* damage.

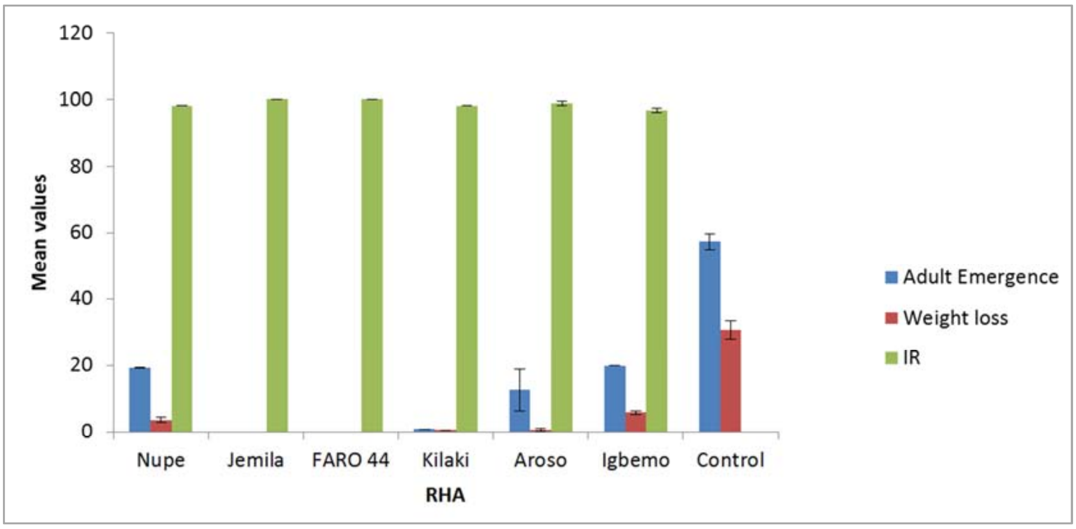

Figure 9. F1 adult emergence, IR and percentage weight loss in maize treated with 0.8 g dosage of different RHAs against *S. zeamais* damage.

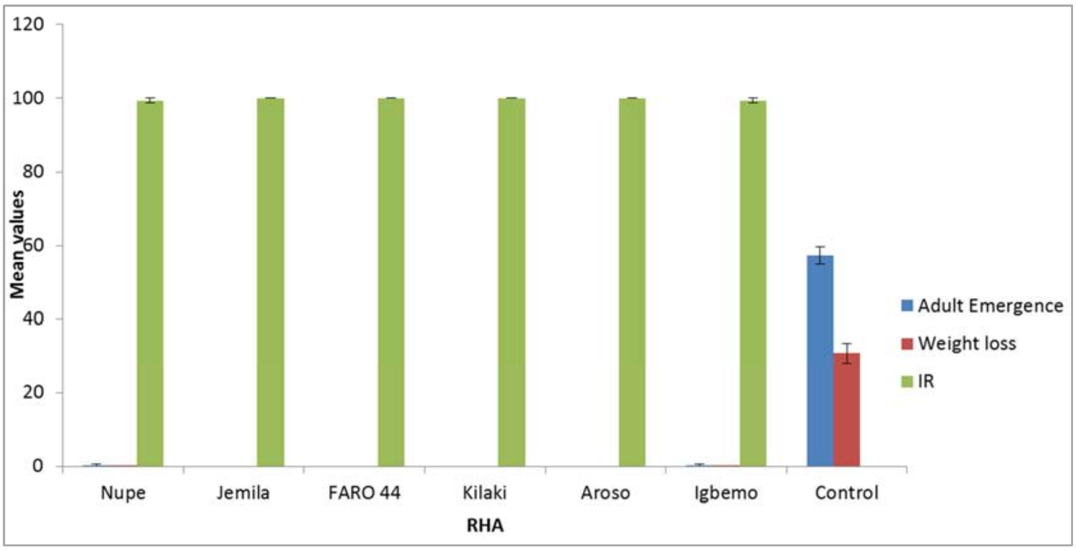

Figure 10. F1 adult emergence, IR and percentage weight loss in maize treated with 1.0 g dosage of different RHAs against *S. zeamais* damage.

4. Discussion

The results of this study showed that RHAs obtained from the six rice varieties grown in different geographical locations in Nigeria manifested a good degree of protection against possible damage by *C. maculatus* and *S. zeamais* in stored grain. Many other workers have also experimentally proven protection capacity of RHA against grain damage by storage beetles in different countries [14, 8, 9, 10]. Clearly, there is justification for use of RHA by rural farmers for storing grains [15, 8, 10]. Many other plant ashes are traditionally used in different developing countries for protecting stored grain from insect damage [16, 7].

The mitigation against damage by the storage beetles by the RHAs observed in this study was presumably partly due to the ability to adversely affect the oviposition and egg eclosion with respect to *C. maculatus*. Significantly fewer eggs were laid by the beetle on grain protected by the RHAs. This may be partly due to the abbreviated adult life since RHA is lethal to the adult beetles [9, 17]. It is also possible that some of the few eggs laid are killed by the RHAs [9, 18]. Adverse effect on oviposition and egg eclosion will correspondingly produce reduced adult emergence. With respect to *S. zeamais* there was similarly significant reduction in adult emergence in infested grain treated with the RHAs putatively due partly to mortality of the introduced adults [19], thus preventing reproduction. With reduced oviposition and egg eclosion in *C. maculatus* and reduced adult emergence in both beetles, the protected grain suffered significantly lower seed damage and weight loss as was appropriately reflected in the lower weevil perforation index in cowpea grain.

It was interesting to observe that there was significant variation in the ability of RHA obtained from six different rice varieties to protect infested grain from depredation by *C. maculatus* and *S. zeamais*. Hitherto, differences had been reported in the abilities of ashes from different plant species to mitigate damage to stored grain by storage beetles [7, 10, 20]. RHA obtained from Jemila rice (from Kaduna State), surpassed all the other ashes in protecting grain infested by the beetles with respect to gain weight loss and perforation at the lowest dose (0.2 g/20 g of grain), the two parameters which may be considered as most important to farmers as well as other grain handlers. Incidentally, 2% of stored grain or less, is the amount suggested for insecticidal plant powders that may be practicable in grain protection against insects [21].

The ability of RHA to control storage beetles infesting grain has been linked principally to its silica (SiO_2) content that makes it lethal to adult beetles, and oviposition deterrence and ovicidal activities [8, 22, 9]. Of the RHAs from the different rice varieties used in this study, only the JRHA has silica content greater than 90% similar to that contained in insecticidal diatomaceous earths [8].

At the suggested effective and practicable dosage for insecticidal powders (i.e. 0.2 g/20 g of grain), even grain protected with JRHA as observed in this study may still suffer some damage by the storage beetles. Ways of enhancing the efficacy of insecticidal plant powders have been enunciated by [23] including, formulation in cocktails, and combination with non-chemical methods of insect control such grain resistance, hermetic storage and entomopathogenic fungi and nematodes, in integrated storage pest management. These should be subjects for further research.

5. Conclusion

Rice Husk Ash (RHA) from six different rice varieties from Nigeria showed significant insecticidal effects against *C. maculatus* and *S. zeamais* infestation when compared to the control. Jemila RHA appeared the most effective against *C. maculatus* and *S. zeamais* as it was able to reduce the oviposition and adult emergence rate of the insects and as well hindered ability of the insects to cause seed damage and weight loss in protected cowpea and maize grains.

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