Applied Tropical Agriculture

Potentials of rice husk ash, cowdung ash and powdered clay as grain protectants against *Callosobruchus maculatus* (F) and *Sitophilus zeamais* (Mots)

Adebayo, R.A.* & Ibikunle, O.

Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, PMB 704, Akure, Nigeria. raphael.adebayo@yahoo.com, raadebayo@futa.edu.ng. *Corresponding author, +2347038661128

ABSTRACT

Experiments to assess the potential of cowdung ash, rice husk ash, and powered clay in the control of Callosobruchus maculatus (F) (cowpea beetle) and Sitophilus zeamais (Mots) (maize weevil) were conducted at the Entomology laboratory of the Department of Crop, Soil and Pest Management, Federal University of Technology, Akure, Ondo State, Nigeria from April – July, 2011. The experiment was carried out under laboratory conditions of 28°±2°C temperature and 55-75% relative humidity. Twenty clean uninfested seeds of cowpea and maize were weighed and placed in petri–dishes to which 1g and 2g of decarbonized ash of rice husk, cowdung and powdered clay were applied as well as the control. All treatments were replicated three times. Data were taken on number of eggs laid, number of seeds with eggs, number of seeds with holes, adult emergence and weight loss for C. maculatus while adult emergence, seeds with holes and weight loss were taken for S. zeamais. The effects of the various concentrations of the treatments on the number of cowpea seeds with C. maculatus eggs were not significant (P>0.05), though the highest number of eggs was recorded on the control (0g). The lowest number of C. maculatus adults emerged from seeds treated with cowdung ash, which was significantly different (P<0.05) from that of the control. Significant higher weight loss was recorded on untreated cowpea seeds which was significantly different from those treated with rice husk ash and cowdung ash. For maize, number of S. zeamais adult emergence and seeds with holes were significantly different (P<0.05) for all treatments, with untreated seeds yielding the highest number of adults. Significant differences also existed in the weight loss with highest weight loss observed on untreated maize grains. The study showed that cowdung and rice husk ash as well as powdered clay performed similarly at different rates and their effects seem to increase with the concentration. These treatments exerted protectant properties on the treated cowpea and maize grains. It is therefore recommended that higher rates of these treatments be further evaluated.

Keywords: Rice husk, Cowdung, Ash, Callosobruchus maculatus, Sitophilus zeamais protectants, cowpea, maize

INTRODUCTION

Cowpea, Vigna unguiculata is the commonest, cheapest and readily available source of plant protein in Nigeria (Kochhar, 1981). It is an important legume crops in tropics and sub-tropics. It assumes a staple position in crop food in Africa and especially in Nigeria where it supplies most of the protein requirements of the people. Caswell (1968) reported that Nigeria produces about 800,000 tonnes of cowpea annually, 80% of which comes from the Northern part of the country. However, recent report revealed that ssubstantial part of the world cowpea production comes from Nigeria with about 4 million hectares and approximately 1.7 million tons of beans produced annually (Ofuya, 2003). The mature seeds are an important pulse, chiefly in Africa and are often ground into meal of different kinds, such as bean powder used in preparation of bean cake popularly known as 'Akara', 'Ekuru' and 'Moinmoin' in Yoruba land of Nigeria whereas the immature pods are eaten fresh, frozen or canned (Kochhar, 1981). Attack from cowpea seed beetles, *Callosobruchus maculatus* (F.) has adversely affected the production of cowpea difficult. The species, *C. maculatus,* has drawn attention because it is widely distributed throughout the tropical and sub-tropical regions hence it has become tropicopolitans (Lale, 2002). Ofuya (2001) also reported that cowpea seed beetle is a cosmopolitan pest of stored grain legumes, especially cowpeas in the tropics and sub-tropics. Several damaged seeds are disfigured with egg covers and adult exit holes, consequently they have reduced weights and poor germinability (Ofuya, 2003). Although Caswell (1981) reported an estimated 4.5% infestation after 3 to 4months causing damage by storage bruchids, especially C. maculatus, it has been reported that after six months in storage, 100% seed infestation and damage may be recorded (Alabeek, 1996).

In many parts of the world today, maize, (Zea mais) is the most important foodstuff and provides the daily bread for the population in poor rural areas. In many parts of Africa, maize is a stable cereal crop which has replaced many traditional starchy foodstuffs, such as sorghum and millet, especially in South Africa, Malawi, Zimbabwe, Kenya, Angola, Zambia, Tanzania, Mozambique, Cameroon, Benin, Togo, Ghana, Nigeria and Egypt (CIMMYT, 2004). It is the most important cereal in sub-Sahara Africa and provides many families with the much-needed nutrients. Annual maize demand in sub-Saharan Africa is expected to double to 52 million tonnes by 2020 (CIMMYT, 2004).

Maize, *(Zea mais)* is the third most important cereal in Nigeria. It is one of the most popular crop plants all over the world, grown in over 140 million hectares all over the world (CIMMYT, 2004).

The species is used mainly to produce staple human food like corn flakes, cakes, corn hominy, etc. It is used for the production of local staple food popularly called 'Egbo' by the Yorubas, 'Tuo' by the Hausas, 'Ogi' by the Yorubas and 'Akamu' by the Igbos (Kochhar, 1981). It is also used for livestock feed and as raw material for many industrial products, such as corn starch, corn syrup, corn sugar and corn oil used in cooking.. Attacks by insect and other pests in storage often result in significant losses, including loss of viability. Post-harvest storage of maize is greatly constrained by the maize weevils, *S. zeamais* (Mots). Damage to maize grain begins from the field just before harvest and the insects are carried into the store where the population builds up rapidly (Appert 1987; Adedire and Lajide, 2001).

It is therefore paramount to control the attack by the insect pests if food security and sufficiency is to be achieved. The control of these pests has been mainly through the use of conventional chemicals. The use of conventional dusts (e.g. pirimiphos – methyl, permethrin) and fumigants (e.g. aluminium phosphate) and their effectiveness against C. maculatus storage has been reported by Jackai and Daoust (1986). The control of storage insects like *S. zeamais* has centred mainly on the use of synthetic insecticides (Asawalam et al., 2007). The most popular practice in protecting stored seeds against insect pest damage is the use of synthetic crop protection agents (Ofuya, 2003).

The major setbacks to the use of synthetic pesticides include the risk to the user, high cost of procurement, development of resistant strains and residue in the food crops. The aforementioned have led scientists to investigating plant products as alternative to synthetic pesticide (Lale, 2002). When the chemicals are used improperly they pose risk to man and the environment, a risk that is most common among uneducated rural farmers in Africa (Ofuya, 2003). Insecticides derived from plants and other biological materials could be better replacement for synthetic insecticides in stored products protection (Lale, 2001). Plant products such as vegetable oils, essential oils, crude extracts and powders have been tested against *C. maculatus.* (Lale, 1995; Dales, 1996; Golob et al., 1991; Boeke et al., 2001). Powder of parts of many indigenous plants when applied at 2% of the weight of stored beans will effectively control cowpea seed beetle in storage (Lale, 1994; Ogunwolu and Odunlami 1996; Adedire and Lajide, 2001). Therefore this study seeks to investigate the potentials of cowdung ash, rice husk ash and powdered clay as grain protectants against *C. maculatus* (F.) and *S. zeamais* (Mots.).

MATERIALS AND METHODS

Study area

The study was conducted at the Analytical and Research Laboratory of the Department of Crop Soil and Pest Management, Federal University of Technology, Akure, Nigeria. Experiments were carried out under ambient laboratory conditions of 28°C±2°C and 65-75% temperature and relative humidity relatively.

Cowpea, Ife-brown and Maize, SUWAN-ISR varieties were obtained from the Institute of Agricultural Research and Training (IAR&T), Ibadan, Oyo State.
Dry cow dung was obtained from the Teaching and Research Farm, Federal University of Technology Akure (FUTA), Nigeria. Rice husks were sourced from a rice milling shed at Ikole-Ekiti, Ekiti State, Nigeria, while the dry red clay was collected from the department of Industrial Design, FUTA. Initial culture of Cowpea beetles and Maize weevils were both obtained from the entomology section of the Analytical and Research Laboratory of the Department of Crop, Soil and Pest Management, FUTA.

Preparation of Treatments

The cowdung was sun-dried, carefully picked to remove any external contaminants that may cause adulteration. Thereafter, the dry cowdung was crumbled it into small particles. The small sized particles were placed in the earthen pot and heated for about 4 hours for decarbonization. The ash collected was allowed to cool and then stored in air tight container under prevailing laboratory conditions. The rice husk was decarbonized into ash at 5 hours using the same procedure as cowdung. The ash was also kept in an air tight container in the laboratory. Dry red clay was pulverized into fine powder with the use of mortar and pestle. The pulverized clay was sieved, using 200 mm wire mesh sieve and was also stored in an air tight container under laboratory conditions.

Culturing of the insects

A culture of C. maculatus was set-up at ambient conditions of 28 – 30°C and 65- 75% relative humidity in the laboratory. This was done by weighing about 250g of clean un-infested cowpea seeds into transparent plastic containers, which was later infested with fifty (50) pairs of adults' C. maculatus from a colony originating from already infested cowpea seeds that were maintained as a pure culture in the laboratory. The containers were covered with fine net to prevent escape and contamination of the culture. They were left on the shelf for breeding and multiplication (Idoko and Adebayo, 2011). The same procedures were followed for the setting up of the culture for Sitophilus zeamais.

TREATMENTS APPLICATION

Cowpea seeds were sterilized in the oven at 70°C for 3 hours and allowed to cool to room temperature (Allotey and Azalekor, 2000). Twenty clean seeds were weighed and placed in sterilized petri–dishes to which 1g and 2g of ash of rice husk, cowdung and powdered clay were applied as well as the control. All treatments were replicated three times. Three pairs of newly emerged 48 hours old adult insects were collected from the culture of *C. maculatus* and placed in the petri–dishes containing the 20 clean un-infested seeds. The petri –dishes were left for 48 hours to allow for oviposition, after which the insects were removed, and the number of seeds with eggs, as well as the number of eggs on each seeds were counted and recorded. Then 1 gram and 2 grams of each treatment (cow dung ash, rice husk ash and powdered clay) were weighed and applied to the cowpea seeds singly in the petri–dishes. Each treatment was thoroughly mixed with the infested cowpea seeds. The controls were left without application of any of the treatments. The petri–dishes were left undisturbed in the laboratory for 21 days for the emergence of adults. From the 21st day of infestation, adult emergence were observed, counted and recorded for four days. The seeds with holes were counted as well as the number of holes on each seeds.

Five pairs of newly emerged 48 hours old unsex adults of S. zeamais were collected from the culture of the species and placed in the petri–dishes containing 20 clean un-infested maize grains. The petri–dishes were left for 3 days to allow for oviposition, after which the insects were removed. Then 1 gram and 2 grams of each treatment (cow dung ash, rice husk ash and powdered clay) were weighed and applied to the petri–dishes containing the clean maize grains. Each treatment was replicated three times. The treatments were thoroughly mixed with the maize grains. The controls were left without application of any of the treatments. The petri–dishes were then left undisturbed in the laboratory for 30 days for the emergence of adults. At 30 days of infestation, the adult emergence was observed, counted and recorded for four days. The seeds with holes were counted as well as the number of holes on each seeds. The weight loss was also determined by weighing the grains after adult emergence. Prior to weighing, the grains were well dusted with the use of carmel hair brush to ensure accurate measurement of weights.

Data analysis

The experimental design used was Completely Randomized Design. Analysis of data was done using SPSS version 15.0 with one way ANOVA. Prior to analysis all data obtained by counts were transformed using square root while analysis of variance was performed to determine significant differences between treatments. Significant means were separated using Duncan Multiple Range Test (DMRT) at 5% level of significance.

RESULTS

The results from this study revealed the effectiveness of the treatments on C. maculatus. Cowdung ash, rice husk ash and powdered clay exert protectant properties on the treated grains against C. maculatus attacks. It was also observed that the

Table 1: Effects of treatments at a rate of 1g on *Callosobruchus maculatus*

Treatments(1g)	No of seeds with eggs	Oviposition	Adult emergence	Number of seeds with holes	Weight loss (gram)
Cowdung ash	4.42a (19.0)	1.98b (3.7)	2.08b (4.0)	3.98b (15.3)	0.56b
Rice husk ash	4.38a (18.7)	1.95b (3.3)	2.41ab(5.6)	4.22ab(17.3)	0.59b
Powdered clay	4.41a (19.0)	1.95b (3.3)	2.79a (7.3)	4.41a (19.0)	0.83a
Control	4.46a (19.3)	2.41a (5.6)	2.80a (7.3)	4.48a (20.6)	1.09a

Means followed by the same letter along the column are not significantly different at 5% significance level. Untransformed data in parenthesis.

Application of treatments at a rate of 1g showed no significant difference on the number of seeds with eggs (Table 1). However, the number of seeds with eggs was slightly higher under control treatment than other treatments. For oviposition, the number of eggs laid on untreated seeds and was significantly higher ($p<0.05$) than those under the other treatments. Least number of adults emerged from seeds treated with cowdung ash, which was significantly lower than those from the control treatment. Seeds that were holed were significantly lower when treated with cowdung ash whereas highest number was recorded on untreated seeds. Significantly higher weight loss was observed under the control treatment though it was not different statistically ($p>0.05$) from those obtained from seeds treated with rice husk ash but significantly lower than the weight loss under powdered clay and control treatments (Table 1).

The trend of the results for 2g of the treatments in Table 2 below are similar to what was observed when 1g of each the treatments was applied to the seeds. The effect of treatments on the number of seeds with eggs was not significantly different ($p>0.05$). Control treatment allowed the highest number of eggs to be oviposited, which were significantly higher than the oviposition of seeds treated with cowdung ash and rice husk ash (Table 2). Trends observed on adult emergence showed that higher number of C. maculatus adults emerged from untreated seeds (control), which was not significantly different from those that emerged from seeds treated with powered clay, but both were significantly higher than the number of C. maculatus adults that emerged from cowdung and rice husk ash treated seeds. The number of seeds with holes for cowdung ash, rice husk ash and control treatments were statistically similar significantly but the three are significantly higher the number of seeds with holes for rice husk treated seeds. Treatment had significant effect on weight loss, with control and cowdung treatments having the highest and lowest weight loss, respectively.

Table 2: Effects of treatments at a rate of 2g on *Callosobruchus maculatus*

Treatments(2g)	No of seed with eggs	Oviposition	Adult emergence	Number of seed with holes	Weight loss (gram)
Cowdung ash	4.49a (19.6)	1.95b (3.3)	2.31b (5.0)	4.22a (17.3)	0.65b
Rice husk ash	4.42a (19.0)	1.76b (2.6)	2.53b (6.0)	4.09b (16.3)	0.84ab
Powdered clay	4.49a (19.6)	2.07ab (4.0)	2.97ab(8.0)	4.46a (19.3)	0.86ab
Control	4.86a (20.3)	2.58a (5.2)	3.13a (9.3)	4.22a (17.3)	1.39a

Means followed by the same letter along the column are not significantly different at 5% significant level. Untransformed data in parenthesis.

The results obtained on treated maize showed that the treatments were effective on the maize weevil. From Table 3 below the result showed that the effect of 1g of the various treatments of S. zeamais adult emergence was significantly different. Significantly higher number of adults emerged from grains treated with powdered clay and control compared with those treated with Cowdung ash and rice husk ash (Table 3). Untreated grains produced highest number of grains with holes, which was statistically different from those obtained on seeds treated with all the other treatments. Weight loss was significantly higher ($p<0.05$) in untreated seeds than the other treatments.

Table 4: Effects of treatments at a rate of 2g on *Sitophilus zeamais*.

Treatments(2g)	Adult emergence	Number of seed with holes	Weight loss (gram)
Cow dung ash	1.35b (1.3)	3.22b (10.3)	0.12b
Rice husk ash	1.35b (1.3)	3.51a (12.0)	0.05c
Powdered clay	1.46a (1.7)	3.13b (9.2)	0.19a
Control	1.55a (2.1)	3.76a (12.5)	0.29a

Means followed by the same letter along the column are not significantly different at 5% significance level. Untransformed data in parenthesis.

DISCUSSION

The results obtained in this study tend to justify the practice by some farmers in West African, who mixes clay powder or ash from animal dung in the storage of cowpea seeds against depredation by storage insects. The treatments have been observed to significantly reduce the ability of *Callosobruchus maculatus* to lay eggs on the protected seeds and thus lead to a reduction in the level of damage (Giga and Chinwanda, 1994). Ash and powder from plants similarly act in this manner (Ofuya, 1986; Wolfson et al, 1991; Apuuli et al, 1996). Powder or ash from animal dung did not manifest any ovicidal and larvicidal activity against *C. maculatus* as adult still emerged from all rates of treatment applied (Dick and Credland, 1984). Thus, seeds which bear eggs or developing larvae prior to and during treatment will be damaged, which might have accounted for damages done on the treated seeds. Powdered clay, ash from animal dung as well as ash from rice husk were either unable to kill *C. maculatus* bruchid within this period of time because it coincided with the time when females lay majority of the eggs (Dick and Credland, 1984). Powder from animal dung, like use of sand (Kranz et al., 1977) or wood ash (Wolfson et al.1991) may act as a physical barrier preventing adults to locate mates or gain access to the seeds or in some other ways disrupt oviposition behaviour.

The greater the amount ash from animal dung that was applied, the greater the adverse effect on beetle oviposition (Lale, 1995) but converse was observed during this study. It is clear that mixing cowpea seeds with ash from animal dung did not completely prevent infestation and damage by C maculatus and *S. zeamais*. Nevertheless, the result of this study supports the submission that rates of ashes as low as 1.0g/20g of seeds may still be applied by famers because of the high tolerance of poor quality produce in the tropics (Taylor, 1981).

Weight loss of bean to bruchids infestation is usually related to quantitative loss of produce that is measured as a reduction in weight or volume, and hence can be valued and measured more efficiently. However, a reduction in weight may not necessarily be as result of feeding by insects, but also reduction in moisture content of the produce. Actual weight loss usually happens from feeding by storage pests (Espinal, 1993). This weight losses indicated in this work justifies the need for the control of storage insect pests.

Result of this study supports the submission of Ofuya (2003) that powder of parts of many indigenous plants will effectively control the cowpea seed beetle when applied on stored beans. Powders of plant and animal products have been tested against *C. maculatus* by Boeke et al. (2001) and similar results with those of the present study obtained. Previous work on the ashes of some bioactive plant species showed that they cause mortality, oviposition deterrence and/or ovicidal action resulting in reduced progeny production of stored product insects (Akob and Ewete, 2007). The mechanisms of their protective action against the cowpea seed beetle include inhibition of oviposition by female beetles and forming barrier to movement (Stoll, 1988). Similar effects of plant materials as crop seeds protectants have been observed in the treatment of cowpea and maize (Ofuya and Dawodu, 2002; Asawalam et al., 2007; Ewete et al., 2007).

The weight loss observed in maize grains due to weevil infestation is in consonance with the submission of Adedire (2001) that production of maize was constrained by *Sitophilus zeamais* when in storage. The infested maize seeds contained ragged holes through which the adult emerged which was similar to what was reported by Sahaf *et al.* (2008). Though grain yield loss of 50 to 100% was reported by Van Wyk et al (2009) and estimated 10% global postharvest grain crop loss by (Boxall et al., 2002), it was evident from this study that ashes from plant and animal products reduced weevil infestation and consequently the weight loss.

Effectiveness of insecticidal property of any plant material depends on the active constituents of the plant material (Idoko and Adebayo, 2011). The active constituent in these plant materials appears to be responsible for their insecticidal properties against the maize weevil. This was responsible for the protectant ability of the tested materials in this study. Many of the active constituents have been reported to possess contact, stomach and respiratory poisoning properties attributed to them (Stoll, 1988; Lale, 2002).

CONCLUSION AND RECOMMENDATION

Generally, cow dung ash and rice husk ash treatments were found to be more effective among the control and three treatments used on cowpea and maize grains for protection of against the attacks of *C. maculatus* and *S. zeamais*. Furthermore, effects of all the treatments applied on the measured parameters

seem similar with few exceptions. This together with the problems of health risks and environmental pollution, owing to misuse of synthetic chemicals, provide good arguments for carrying out this study on natural pesticides. Thus the tested products could serve as good botanicals for the management of storage insect pests. It is therefore, recommended that more studies be carried out on the potentials of application of higher rates of these plant botanicals against the insect pests of stored grains.

REFERENCES

Adedire, C.O. and Lajide, L. (2001). Efficacy of powders of some tropical plants in the control of pulse beetle. Applied Tropical Agriculture, 6: 11-15.

Alebeek, F.A.N. (1996). Natural suppression of Bruchid pest in stored cowpea *Vigna unguiculata* (L) Walp in West Africa. International Journal of Pest Management, 42: 55-60.

Allotey, J. and Azalekor, W. (2000). Some aspects of the biology and control using botanicals of the rice moth, Corcyra *cephalonica* (Stainton), on some pulses. J. stored prod. Res., 36 (3): 235-243.

Apuuli, J.K.K. and M.H. Villet. (1996). The use of wood ash for the protection of stored cowpea seed (Vigna *unguiculata* (L) against Bruchidae. African Entomology. 102: 97-99.

Asawalam, E. F, Emosairue, S. O., Ekeleme, F. and Wokocha, R. C. (2007). Insecticidal effects of powdered parts of eight Nigerian plant species against maize weevil *Sitophilus* zeamais Motschulsky (Coleoptera: Curculionidae). Electronic Journal of Environmental, Agriculture and Food Chemistry, 6 (11): 2526-2533.

Boeke, S. J., van Loon, J. J.A., van Huis, A., Kossou, D.K. and Dicke, M. (2001). The use of plant material to protect stored leguminous seeds against seed beetles: a review.. Backhuys Publishers, Netherlands, 108 pp.

Caswell, G. H. (1981). Damage to stored cowpea in the Northern of Nigeria. Samaru Journal of Agricultural Research, 1: 11-19.

Caswell, G.H. (1968). The Storage of Cowpea in the Northern State of Nigeria. Proc. Agric. Soc. Nig. Pp. 4-6.

Dales, M.J. (1996). A review of plant materials used for controlling insect pests of stored products. NRI bulletin 65, Chatham, UK: Natural Resource Institute. 65: 1-84

Espinal, J.R. (1993). Economic losses associated with Zabrotes subfasciatus (Boheman) (Coleoptera: Bruchidae) and *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) infestations of stored dry red beans (Phaseolus vulgaris L.) in southeastern Honduras. Unpublisged Ph.D. Dissertation, Kansas State University, Kansas, USA, 210 pp.

Ewete, F.K., Ashimolowo, O.R. and Adohi, E.A. (2007). Survey of plants used in maize storage in Abeokuta North Local Government Area and the efficacy of a selected species against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae). Nigerian Journal of Entomology, 24: 119–126.

Giga, D.P. and Chinwanda, (1994). Efficacy of armorphus silica dust against bean bruchids. In E. highly, E.J wright, H.J. banks and B.R. Champ (eds), Proceedings of the 6th international Working Conference on Stored-product protection 2:631-632.

Golob, P., Moss, C., Males, M., Fidgen, A. and Evans, J. (1991). The spices and medicinals as bioactive protectants for grains. FAO, Rome, 23 pp.

Idoko, J.E. and Adebayo, R.A. (2011). Efficacy of Single and Combined Leaf Powder of Nicotiana Tabacum L. [Solanales: Solanaceae] with Reduced Rates of Pirimiphos-Methyl in Management of Sitophilus Zeamais Motschulsky [Coleoptera: Curculionidae]. Journal of Agricultural Science. 3(1): 276-280.

Jackai, L.E.N. and Daoust, R.A. (1986). Insect pests of cowpeas. Annual review of entomology 31: 95- 119.

Kochhar S.L. (1981). Economic Botany in the Tropics. 2nd Edition. University of Delhi, London: Macmillan India Ltd.131pp

Kranz, J. Schmutterer, H and Koch, W. (Editor). (1977). Diseases, Pests and Weeds in Tropical Crops. John Willey and sons, Chichester. 666, pp.

Lale, N.E.S. (1994). Laboratory assessment of the effectiveness and persistence of powders of four spices on cowpea bruchid and maize weevil in airtight facilities. Samaru Journal of Agricultural Research, 11: 79- 84.

Lale, N.E.S. (1995). An overview of the use of plant products in the management of stored product coleopteran in the tropics. Postharvest News and Information, 6: 69- 75.

Lale, N.E.S. (2001). The impact of storage insect pests on post- harvest loss and their management in the Nigeria agricultural system. Nigerian Journal of Experimental and Applied Biology, 2: 231- 239.

Lale, N.E.S. (2002). Stored Product Entomology and Acarology in tropical Africa. Mole publication, Maiduguri, Nigeria. 204 pp.

Ofuya, T.I. (1986). Use of wood ash, dry chilli pepper fruits and onion scale leaves for reducing C. maculatus (F) damage in cowpea seeds during storage. Journal of Agricultural Science, 107: 467- 468.

Ofuya, T.I. (2001). Biology, ecology and control of insect pests of stored legumes in Nigeria. In pests of stored cereals and pulses in Nigeria: Biology, Ecology and Control (edited by T.I. Ofuya and Lale, N.E.S). Dave Collins publication, Nigeria, pp 24-58.

Ofuya, T.I. and Dawodu E.O. (2002). Aspects of Insecticidal Action of *Piper guineense* Schum and Thonn Fruit Powders against Callosobruchus maculatus (F.) (Coleoptera: Bruchidae). Nigerian Journal of Entomology, 19: 40-50.

Ofuya, T.I. (2003). Beans, insects and man. Inaugural lecture series 35. The Federal University of Technology, Akure, Nigeria. 45 pp.

Ogunwolu, O. and Odunlami, A.T. (1996). Suppression of seed bruchids *Callosobruchus maculatus* (F.) development and damage on cowpea *Vigna unguiculata* (L) Walp with *Zanthoxylum zanthoxyloides* (Lam.) Waterm. (Rutaceae) root bark powder when compared with neem seed powder and pirimiphos-methyl. Crop Protection, 15: 603-607.

Sahaf, B.Z., Moharramipour, M.H. and Meshkatalsadat. (2008). Fumigant toxicity of essential oil from Vitex pseudo-negundo against *Tribolium castaenum* (Herbst) and Sitiphilus oryzae (L.). Journal of Asia-Pacific Entomology 11 (4): 175-179

Stoll, G. (1988). Natural plant protection in the tropics. AGRECOL, Margraf Publishers Scientific Books, Weikersheim, Germany.188pp

Taylor, T.A., (1981). Distribution, ecology and importance of Bruchids attacking grain legumes and pulses in Africa. In: V. Labeyrie (Echtor), The Ecology of Bruchids Attacking Legumes (Pulses), Junk, The Hague, pp. 199-203.

Van Wyk, B.E., Van Oudtshoorn B. and Gericke N. (2009). Medicinal plants of South Africa, Briza Publications, Pretoria, south Africa. 336p

Wolfson, J. L., Shade, R.E., Mentzer, P.E. and Murdock, L.L. (1991). Efficacy of ash for controlling infestations of Callosobruchus maculatus (F). Journal of Stored Production Research. 27: 239-244.