

Efficacy of aqueous leaf extracts *Azadirachta indica* and *Moringa oleifera* in the control of *Callosobruchus maculatus* (F.) on stored cowpea

* Uddin II R. O. and Ogundele S. M.

Department of Crop Protection, Entomology Unit, Faculty of Agriculture, University of Ilorin, Nigeria.

*Corresponding author's email and phone: -ruddin11@yahoo.com; +2348033608948

Abstract

The aqueous leaf extracts of *Azadirachta indica* and *Moringa oleifera* were evaluated as grain protectants against the cowpea weevil *Callosobruchus maculatus* in the laboratory. The study was carried out in the laboratory of the Department of Crop Protection, University of Ilorin. The extracts were applied at the following rates, -0.5, 1.0, 1.5 and 2.0 ml/20g cowpea seeds. There were three treatments and each treatment was replicated four times in a completely randomized design experiment. Six newly emerged adult *Callosobruchus maculatus* in a 1:1 (male: female) ratio were introduced into 20g of treated seeds. The parameters used to assess the efficacy of the treatments include adult mortality, oviposition rate, larva and pupae emergence and F_1 progeny emergence. *Azadirachta indica* and *M. oleifera* at 2.0 ml/20g seeds resulted in a significant increase in mortality of *C. maculatus*. Oviposition, larva emergence, pupa emergence and F_1 progeny emergence decreased significantly ($P \leq 0.05$) when cowpea seeds were treated. *Azadirachta indica* at 2.0ml was the most effective in reducing the F_1 progeny emergence. Though *M. oleifera* was not as effective as *A. indica* in protecting the cowpea seeds, it was significantly better than the control. Farmers in developing countries can use *A. indica* at 2.0ml as a good alternative in rural grain storage instead of the expensive insecticides.

Keywords: Botanicals, *Callosobruchus maculatus*, cowpea, efficacy, storage

Introduction

Cowpea *Vigna unguiculata* L. (Walp) is one of the most important grain legumes cultivated in the semi-arid areas of the tropics and sub-tropic regions of the world (Ntoukam et al., 2000). The world cowpea production in 2001 was estimated as 3.3 million tons grown on 122.5 million

hectares (FAO, 2004), of which West and Central Africa are the leading cowpea producing regions in the world. These regions produce 64% of the total estimated 3.3 million tons of cowpea seeds produced annually (FAO, 2004). The world average yield was 337 kg per hectare, while the average yield in Nigeria was 417 kg per

hectare and in Niger it was 171 kg per hectare (IITA, 2002).

Cowpea plays an important role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein which is a key factor in alleviating malnutrition among women, children and livestock in resource limited households (Cook et al., 2005). It is also a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding cereal crops grown in rotation with it (Adedire, 2009). Cowpea is a pulse and is commonly stored as staple for man and animals. Abulude et al. (2007) and Nyambo (1993) reported losses of between 20 – 50% on stored cowpea and sometimes 100% loss due to attack by the cowpea weevil, *Callosobruchus maculatus*. In addition to the direct damage, losses also occur as a result of contamination of the stored grains with faecal droppings, nitrogenous waste (frass) and exuviate (Udo, 2000). *Callosobruchus maculatus* attack initially begins in the field and rapidly builds up during storage. Maina et al. (2011) stated that 100% infestation of pulse grains can occur after three to six months storage, resulting in about 60% weight loss (Tanzubil, 1991; Umeozor, 2005). Efforts have been made by farmers and government agencies to control and or reduce infestation and attack of stored cowpea by the bean weevil. Over the years in Nigeria and in other parts of the world, *C. maculatus* management on the field and in storage has been dominated by chemical

control using fumigants and synthetic insecticides (Akinkulere et al., 2006). CAPE (2009) reported that the World Health Organization (WHO) estimates that 200,000 people are killed worldwide every year, as a result of pesticide poisoning. Dubey et al. (2011) and Khater (2011) reported that the use of synthetic chemicals has been restricted because of their carcinogenicity, teratogenicity, high and acute residual toxicity, ability to create hormonal imbalance, spermatotoxicity, long degradation period and deposition of toxic residues in food. Addor (1995) also reported that in addition to their persistency, there have also been reported cases of resistance, pest resurgence and secondary pest outbreaks when these pesticides are used.

The problems associated with the use of synthetic pesticides have necessitated the search for natural methods of control which are friendly, affordable and are readily available to provide adequate supply to meet the insecticide shortage. Alternatives therefore to chemical treatment of stored cowpea have been developed consistently over the years with many researches being turned to the use of botanicals and plant products in the safe storage of cowpea (Ogunleye, 2004). This work aims at evaluating the effectiveness of aqueous extracts of *Azadirachta indica* and *Moringa oleifera* in controlling *Callosobruchus maculatus* infesting cowpea in storage.

Materials and Methods

The experiment was carried out at the laboratory of the Department of Crop Protection, University of Ilorin, Ilorin, Nigeria (8.4910°N, 4.5952°E). The cowpea seed used for the experiment was a local brown variety procured from a local market (Oja-oba) in Ilorin, Kwara State. The botanicals used were *Azadirachta indica* (Neem) and *Moringa oleifera* (Miracle tree). These botanicals were sourced around Tanke area in Ilorin and the premises of the University of Ilorin.

The initial stock culture of *C. maculatus* used for the experiment was obtained from the Nigerian Stored Products Research Institute Ilorin. This was maintained in the laboratory of the Department of Crop Protection, Faculty of Agriculture at ambient temperature. Fresh leaves of *A. indica* and *M. oleifera* were removed from their stem. 500g each of neem and moringa were separately blended in an electric blender and the homogenized substrate was added to 1 litre of distilled water in a plastic container (24cm x 23cm). The mixtures were vigorously stirred and allowed to stand for 24 hours. After 24 hours, the mixtures were stirred again before they were filtered using a muslin cloth. The resultant filtrates were then put in plastic bottles (1.5litre) and kept in the refrigerator until they were needed.

The experimental design was a completely randomized design having three treatments and four replicates per treatment. 20g seeds

were weighed and placed inside transparent plastic containers (250ml). The aqueous leaf extracts of the botanicals were introduced into the containers using a micro syringe at the following rates: - 0.5ml, 1.0ml, 1.5ml and 2.0ml. The treated seeds in the plastic container were then shaken to allow for even coating of the seeds by the aqueous extracts. The set-up was left to stand for 1 hour in order for the aqueous extracts to air dry on the seeds.

Six newly emerged adult *C. maculatus* in a ratio 1:1 were introduced into each replicate. The containers were tightly covered using a muslin cloth and firmly screwed using the perforated lid of the plastic container. The effects of the aqueous extracts were assessed using the following parameters, adult mortality, oviposition, larvae emergence, pupae emergence and F₁ progeny emergence. The data collected were analysed using the Analysis of Variance. The means were separated using the new Duncan Multiple Range Test. The SPSS statistical package (version 21) was used for the analysis.

Results and Discussion

The study shows that the aqueous leaf extracts of *Azadirachta indica* and *Moringa oleifera* were able to protect stored cowpea against *Callosobruchus maculatus* infestation. The aqueous extracts of *M. oleifera* and *A. indica* increased the mortality of *C. maculatus*. *Azadirachta indica* at 1.5ml/20g and *M. oleifera* at 2.0ml/20g were most effective in increasing

adult mortality and this was significantly different ($P < 0.05$) from the control (Table 1). The resultant high mortalities of adult *C. maculatus* on cowpea seeds treated with aqueous leaf extracts of *A. indica* when compared with *M. oleifera* could be attributed to the presence of azadirachtin which is toxic to stored product insect pests (Mbailo et al., 2006). Makanjuola (1989) reported that fecundity, hatching and adult emergence in *C. maculatus* and adult emergence in *Sitophilus oryzae* were significantly reduced when raised on cowpea and maize respectively treated with extracts of neem leaf and seeds. Shukla et al. (2007) opined that the bitter taste, pungent smell and semio-chemical nature of the plant powders which cause quick mortality within five days would not allow the formation of resistant races of the insects which is quite prevalent with most of the synthetic pesticides.

Lale and Abdulrahman (1999) and Lale and Mustapha (2000) reported a significant reduction in egg laying and adult emergence in *C. maculatus* treated with neem seed oil. Ivbijaro (1983) also reported a significant reduction in egg laying of *C. maculatus* on cowpea mixed with neem seeds. This is consistent with the findings of this work as *Azadirachta indica* and *M. oleifera* at 2.0ml/20g seeds were most effective in reducing the oviposition rate of *C. maculatus* on stored cowpea (Table 2). This was significantly different ($P < 0.05$) at day 9 and 10 when compared with the control. Sadeghi et al (2006) showed that an application of plant lectins to the surface of

chicken peas dramatically reduced oviposition in *C. maculatus*. Makkar and Becker (1996) stated that lectins had not been reported on *M. oleifera*. This could probably be the reason for its reduced efficacy when compared to *A. indica*.

Banken and Stark (1997) reported that azadirachtin inhibits the release of prothoracicotropic hormones and allatotropins and this ultimately affects metamorphosis in insects (Schmutterer and Rembold, 1995). This could be responsible for the observation in this study since the aqueous extracts of *A. indica* and *M. oleifera* at all the rates tested, reduced larval emergence of *C. maculatus*. *Azadirachta indica* and *M. oleifera* at 2.0ml/20g seeds were the most effective in reducing larval emergence but it was not significantly different ($P > 0.05$) from the control (Table 3). The trend was the same for pupal emergence of *C. maculatus* (Table 4). The reduced larval emergence could also be as a result of reduced feeding by the larva which may lead to death. Williams and Mansingh (1996) reported that *Azadirachta indica* also alters insect behaviour because of its antifeedant and repellent action. The antifeedant properties of *A. indica* could account for the reduction in larval emergence due to death from starvation and also from inhibition of larval penetration into the seeds due to feeding deterrence. *Azadirachta indica* treated seeds reduced pupal emergence better than *M. oleifera* in this study and Aldhous (1992) opined that this could be due to inhibition of metamorphosis as a result of azadirachtin which affected the pupal

emergence due to hormonal disturbance control in chitin synthesis during the moulting process.

Azadirachta indica and *M. oleifera* at 2.0ml/20g seeds were most effective in reducing the F_1 progeny emergence of *C. maculatus* and the difference was significant from the 23rd – 30th day after treatment (Table 5). *Azadirachta indica* at 2.0ml/20g seeds significantly reduced F_1 progeny emergence (4.82) when compared with the control (13.65) (Table 5). This reduction in F_1 emergence could be as a result of hormonal disturbance reported by Aldhous (1992) which led to a threefold reduction in the number of F_1 progeny emergence of *A. indica* treated seeds in this study (Table 5), while *Moringa oleifera* had a two (2) fold reduction in the F_1 progeny for the 23rd day after treatment and this was significantly different ($P < 0.05$) from the control (Table 5). This agrees with the work of Boeke et al (2004) who reported that the aqueous extracts and powder of *A. indica*, *Jatropha curcas* and *Vernonia amygdalina* reduced the number of F_1 progeny emergence. Emosairue and Ubana (1998) also found *A. indica* to be effective in reducing progeny emergence. While

Mbailo et al., (2006) and Ileke and Oni (2011) reported that high concentration of *M. oleifera* powder caused a significant reduction in the longevity of adult *C. maculatus* on cowpea seeds and *Sitophilus zeamais* adults on wheat grains respectively.

Conclusion

This study shows the potentials of *A. indica* and *M. oleifera* as plant derived insecticides against *C. maculatus*. Though *M. oleifera* was not as effective as *A. indica*, it was better than the non-treated cowpea seeds. Farmers could thus be encouraged to use this alternative in rural grain storage instead of the unavailable and expensive pesticides. The use of local resources for the manufacture of plant derived pesticides could make a developing country like Nigeria more independent of pesticide imports and therefore improve the local economy. The availability of plant materials with proven insecticidal potentials can help reduce the problem of scarcity of pesticides. Growing plantations of such plants in appropriate areas could also help in preventing desertification of some areas in the country.

Table 1: Effects of the treatments on mortality of adult *C. maculatus*

Treatment	<i>Azadirachta indica</i>				<i>Moringa oleifera</i>			
	Days After Treatment (DAT)							
	1	2	3	4	1	2	3	4
Control 0.70 ^a	0.96 ^a	1.22 ^a	1.22 ^a	0.70 ^a	0.70 ^a	0.70 ^a	0.96 ^a	
0.5	0.96 ^{ab}	1.40 ^a	1.40 ^a	1.09 ^a	0.96 ^a	1.31 ^b	1.49 ^b	0.96 ^a
1.0	1.22 ^b	1.49 ^b	1.34 ^a	1.25 ^a	1.18 ^{ab}	1.31 ^b	1.63 ^b	0.96 ^a
1.5	1.40 ^b	1.49 ^b	1.49 ^b	0.83 ^a	1.18 ^{ab}	1.40 ^b	1.63 ^b	0.83 ^a
2.0	1.36 ^b	1.63 ^a	1.14 ^a	0.83 ^a	1.31 ^b	1.49 ^b	1.47 ^b	1.09 ^a
SED	0.02	0.02	0.25	0.06	0.05	0.01	0.02	0.20

Means followed by the same letters in a column are not significantly different at $P < 0.05$

SED- Standard Error of Difference

Table 2: Effects of the treatments on oviposition rate of *C. maculatus*

Treatment	<i>Azadirachta indica</i>				<i>Moringa oleifera</i>			
	Days After Treatment (DAT)							
Rate (ml)	7	8	9	10	7	8	9	10
Control 2.72 ^a	3.34 ^a	4.05 ^b	5.42 ^b	3.07 ^a	3.38 ^{bc}	4.62 ^b	5.42 ^b	
0.5	2.04 ^a	2.97 ^a	3.83 ^{ab}	4.34 ^b	1.90 ^a	3.55 ^{bc}	4.75 ^b	5.33 ^b
1.0	2.34 ^a	2.74 ^a	3.43 ^{ab}	4.29 ^b	3.21 ^b	3.83 ^c	4.11 ^b	4.27 ^{ab}
1.5	2.42 ^a	2.88 ^a	3.29 ^{ab}	3.70 ^b	2.52 ^{ab}	2.79 ^{ab}	3.40 ^{ab}	3.71 ^{ab}
2.0	1.47 ^a	1.71 ^a	1.91 ^a	1.91 ^a	1.63 ^a	2.04 ^a	2.32 ^a	2.67 ^a
SED	1.31	0.49	0.53	0.02	0.07	0.03	0.12	0.17

Means followed by the same letters in a column are not significantly different at $P < 0.05$

SED- Standard Error of Difference

Table 3: Effects of the treatments on larvae emergence of *C. maculatus*

Table 3: Effects of the treatments on larvae emergence of <i>C. maculatus</i>										
Treatment	<i>Azadirachta indica</i>					<i>Moringa oleifera</i>				
	DAT (Days after Treatment)									
Rate (ml)	11	12	13	14	15	11	12	13	14	15
Control 1.22 ^b	0.96 ^a	1.22 ^a	0.96 ^a	0.70 ^a	0.96 ^a	0.96 ^a	1.22 ^a	1.22 ^a	1.22 ^a	
0.5	0.83 ^a	0.96 ^a	0.96 ^a	0.70 ^a	0.96 ^a	0.96 ^a	1.18 ^a	0.83 ^a	0.96 ^a	1.18 ^a
1.0	0.83 ^a	0.83 ^a	0.96 ^a	0.96 ^a	1.05 ^a	0.83 ^a	1.05 ^a	0.83 ^a	1.09 ^a	0.96 ^a
1.5	0.70 ^a	0.83 ^a	0.96 ^a	0.96 ^a	1.09 ^a	0.83 ^a	0.83 ^a	0.96 ^a	0.83 ^a	0.83 ^a
2.0	0.70 ^a	0.70 ^a	0.83 ^a	0.96 ^a	0.70 ^a	0.70 ^a	0.70 ^a	0.96 ^a	0.96 ^a	0.83 ^a
SED	0.01	0.09	0.06	0.10	0.05	0.09	0.07	0.08	0.08	0.05

Means followed by the same letters in a column are not significantly different at $P < 0.05$

SED- Standard Error of Difference

Table 4: Effects of the treatments on pupa emergence of *C. maculatus*

Table 4: Effects of the treatments on pupa emergence of <i>C. maculatus</i>						
Treatment	<i>Azadirachta indica</i>			<i>Moringa oleifera</i>		
	Days After Treatment (DAT)					
Rate (ml)	16	17	18	16	17	18
Control 1.40 ^a	0.96 ^a	1.22 ^a		1.22 ^a	1.22 ^a	
0.5	0.96 ^a	1.09 ^a	1.08 ^a	1.31 ^a	0.96 ^{ab}	1.22 ^a
1.0	1.05 ^a	0.83 ^a	0.96 ^a	0.96 ^a	1.18 ^a	1.09 ^a
1.5	1.05 ^a	0.96 ^a	0.83 ^a	0.96 ^a	1.09 ^{ab}	1.09 ^a
2.0	0.96 ^a	0.83 ^a	0.96 ^a	0.96 ^a	0.70 ^a	0.96 ^a
SED	0.22	0.120.08		0.04	0.020.06	

Means followed by the same letters in a column are not significantly different at $P < 0.05$

SED- Standard Error of Difference

Table 5: Effects of the treatments on F_1 progeny emergence of *C. maculatus*

Treatment	<i>Azadirachta indica</i>			<i>Moringa oleifera</i>		
	Days After Treatment (DAT)					
Rate (ml)	23	30	37	23	30	37
Control	13.64 ^b	5.06 ^b	4.28 ^a	13.60 ^b	8.10 ^b	4.72 ^a
0.5	9.63 ^{ab}	3.89 ^a	4.02 ^a	12.47 ^{ab}	5.06 ^a	4.20 ^a
1.0	7.45 ^a	4.02 ^{ab}	3.76 ^a	8.58 ^{ab}	5.36 ^{ab}	3.89 ^a
1.5	8.85 ^{ab}	4.23 ^{ab}	3.63 ^a	8.10 ^{ab}	4.93 ^a	3.76 ^a
2.0	4.81 ^a	3.85 ^a	3.50 ^a	6.53 ^a	3.76 ^a	3.50 ^a
SED	2.00	0.250.22		6.44	1.200.02	

Means followed by the same letters in a column are not significantly different at $P < 0.05$

SED- Standard Error of Difference

References

- Abulude, F.O., Ogunkoya, M.O., Ogunleye, R.F., Akinola, A.O. & Adeyemi, A.O. (2007). Effect of palm oil in protecting stored grains from *Sitophilus zeamais* and *Callosobruchus maculatus*. *Journal of Entomology*, 4: 393-396.
- Addor, R.W. (1995) "Insecticides", In: *Agrochemicals from Natural Products*, Godfrey CRA. Ed., Marcel Dekker, Inc. New York, p. 1. Ahn YJ, Kim GH, Cho KY. Bioassay system for insecticidal compounds. *Proceedings of the 3rd Symposium on the Biochemical Methodology for the Research and Development of the Bioactive Substances*. Seoul, Republic of Korea, p. 495.
- Adedire, C.O. (2009). Safety and policy issues in formulations and use of medicinal plants; In: *Formulation of medicinal plants for crop and animal production in Nigeria: realities and challenges*, proceedings of the 5th Conference (Akure-Humboldt Kellogg)
- Akinkurolere, R.O., Adedire, C.O. & Odeyemi, O.O. (2006). Laboratory evaluation of the toxic properties of forest anchomanes, *Anhomanes difformis*, against pulse beetle, *Callosobruchus maculatus* (Coleoptera: Bruchidae). *Insect Science*, 13: 25-29. <http://dx.doi.org/10.1111/j.1744-7917.2006.00064.x>
- Aldhous, P. (1992). Neem chemicals the pieces fall into place. *Science*. 258: 893.
- Banken, J.A.O. & Stark, J. (1997). Stage and age influence on the susceptibility of *Coccinella septempunctata* after direct exposure to Neemex, a neem insecticide. *Journal of Economic Entomology* 90: 1102-1105.
- Boeke, S.J., Baumgart, I.R., Van Loon, J.J.A., van Huis, A., Dicke, M. & D.K. Kossou, D.K. (2004). Toxicity and repellence of African plants traditionally used for the protection of stored cowpea against *Callosobruchus maculatus*. *Journal of Stored Products Research*, 40: 423-438.
- C.A.P.E (2009). Position statement on synthetic pesticides. 5pp
- Cook, B. G., Pengelly, B.C., Brown, S.D., Donnelly, J.L., Eagles, D.A., Franco, M.A., Hanson, J., Mullen, B.F., Partridge, J.J., Peters, M. & Schultze-Kraft, R. (2005). *Tropical forages*. CSIRO, DPI&F (Qld), CIAT and ILRI, Brisbane, Australia. <http://www.tropicalforages.info>
- Dubey, N.K., Shukla, R., Kumar, A., Singh, P. & Prakash, B. (2011). Global scenario on the application of natural products in Integrated Pest Management Programmes. In: *Natural products in plant pest management*, (Ed.) Dubey, N.K. CAB International. pp. 1-20.
- Emosairue, S.O. & Ubana, U.B. (1998). Field evaluation of neem for the control of some cowpea pests in South Eastern Nigeria. *Global Journal of Pure and Applied Science*. 4 (3): 237-241.

- FAO, (2004). Economic and Social Department.
<http://www.gmocompass.org/eng/crop/18.genetically-modified-cowpeaeu.htm>
- Ileke, K.D. & Oni, M.O. (2011). Toxicity of some plant powders to maize weevil, *Sitophilus zeamais* (Coleoptera: Curculionidae) on stored wheat grains. African Journal of Agricultural Research. 6 (13): 3043-3048.
- IITA. (2002). Annual report, International Institute of tropical Agriculture, Ibadan, Nigeria.
- Ivbijaro, M. F. (1983). Preservation of cowpea, *Vigna unguiculata* (L.)Walp. with the neem seed *Azadirachta indica* A. Juss. Protection Ecology. 5: 177-182.
- Khater, H.F. (2011). Ecosmart Biorational Insecticides: Alternative Insect Control Strategies. In: Insecticides, Perveen, F. (Ed.). In Tech, Rijeka, Croatia, ISBN 979-953-307-667-5.
- Lale, N.E.S. and Abdulrahman, H.T. (1999). Evaluation of neem (*Azadirachta indica* A. Juss) seed oil obtained by different methods and neem powder for the management of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpea. Journal of Stored Products Research. 35: 135-143.
- Lale, N.E.S. and Mustapha, A. (2000). Potential of combining neem (*Azadirachta indica* A. Juss) seed oil with varietal resistance for the management of the cowpea bruchid, *Callosobruchus maculatus* (F.) Journal of Stored Product Research. 36: 215-222.
- Maina, Y.T., Dauda, Z. & Degri, M.M. (2011). Effects of different levels of infestation and storage durations on the development of *Callosobruchus maculatus* (Fab.) in stored cowpea *Vigna unguiculata* (L.) Walp. Production Agriculture and Technology. 7(1): 49-54.
- Makanjuola, W.A. (1989). Evaluation of extracts of neem (*Azadirachta indica* A. Juss) for the control of some stored product pests. Journal of Stored Product Research. 25(4): 231-237.
- Makkar, H.P.S. & Becker, K. (1996). Nutritional value and anti-nutritional components of whole and ethanol extracted *Moringa oleifera* leaves. Animal Feed Science and Technology 63, 211-228
- Mbailo, N., Nanadoum, M, Automne, B. Gabra, B. & Emmanuel, A. (2006). Effect of six common seed oils on survival, egg laying and development of the cowpea weevil *Callosobruchus maculatus*. Journal of Biological Science. 6 (2): 420-425.
- Ntoukam, G., Murdock, L.L., Shade, R.E., Kitch, L.W., Endondo, C., Ousmane, B. & Wolfson, J. (2000). Management insect pests of cowpea in storage. Bean/cowpea midcourse research meeting, April 9-14, Senegal. p 3-4.
- Nyambo, B.T. (1993). Post-harvest maize and sorghum grain losses in traditional and improved stores in South Nyanza

- district, Kenya. International Journal of Pest Management. 39: 181-187.
- Ogunleye, R.F. (2004). Effect of *Zanthoxylum* dusts and extracts on the fecundity, fertility and developmental periods of *Callosobruchus maculatus* (F.) Coleoptera: Bruchidae. Bioscience Research Communications, 16: 53-57
- Sadeghi, A, Van Damme, E.J.M., Peumans, W.J. & Smagghe, G. (2006) Deterrent activity of plant lectins on cowpea weevil *Callosobruchus maculatus* (F.) oviposition. Phytochemistry 67 (2006) 2078-2084
- Schmutterer, H. & Rembold, H. (1995). Neem tree source of unique natural products for integrated pest management, medicine industry and other purposes (ed. Schmutterer, H.), VCH, Weinheim, Germany.
- Shukla, R., Srivastava, B., Kumar, R. & Dubey, N.K. (2007). Potential of some botanical powders in reducing infestation of chicken pea by *Callosobruchus chinensis* L. (Coleoptera: Bruchidae). Journal of Agricultural Technology. 3(1): 11-19.
- Tanzubil, P.B. (1991). Control of some insect pests of cowpea (*Vigna unguiculata*) with neem (*Azadirachta indica* A. Juss) in Northern Ghana. Tropical Pest Management. 37: 216-217.
- Udo, I.O. (2000). Efficacy of Candlewood *Zanthoxylum xanthoxyloides* (Lam.) for the control of three stored product pests. M. Phil. Thesis, University of Ghana, Legon. 79pp.
- Umeozor, O.C. (2005). Effect of the infestation of *Callosobruchus maculatus* (Fab.) on the weight loss of stored cowpea (*Vigna unguiculata* (L.) Walp). Journal of Applied Science and Environmental Management. 9 (1): 169-172.
- Williams, L.A.D. & Mansingh, A. (1996). The insecticidal and acaricidal actions of compounds from *Azadirachta indica* A. Juss and their use in tropical pest management. International Pest Management Review. 1: 133-145.