Research Journal of Agronomy 1 (2): 88-93, 2007

Effects of Plantain Inflorescence Ash and Neem Seed Extracts on the Yield and Insect Pests of Eggplant (*Solanum melongena* L.) In Calabar, Nigeria

[1]D.A. Ukeh, [1]S.B.A. Umoetok, [1]Paschal Iwejuo and [2]S.O. Emosairue
[1]Department of Zoology, University of Aberdeen, Tillydrone Avenue, AB24 2TZ, United Kingdom
[2]Department of Agronomy, Delta State University, Asaba Campus, Asaba, Nigeria
[1]Department of Crop Science, University of Calabar, Nigeria

Abstract: Field experiments were conducted between April and July 2005 to evaluate the effects of plantain inflorescence stalk ash and crude neem products on the insect pests and yield of eggplant, *Solanum melongena* L. in Calabar, southern Nigeria. The experiments were conducted in randomised complete block designs consisting of four formulations of each plant product plus the control making 5 treatments each. Plantain ash concentrations were as effective as neem oil and water extracts in the prevention of pests colonization of the crop. Statistical analysis also showed that both plant products significantly ($p<0.001$) increased the yields of *S. melongena* than the untreated plots. In plantain ash treated plots, 5% ash concentration produced 2.28 kg fresh fruits weight and 23.2 fruits per plant, while the untreated yielded 0.94 kg fresh fruits weight and 11.8 fruits per plant, respectively. In neem products experiment, 5% Crude Neem Oil (CNO) yielded 1.78 kg fruits and 24 fruits per plant, while the untreated produced 0.9 kg fruits and 16 fruits per plant, respectively.

Key words: *Solanum melongena*, neem oil, neem seed kernel extracts, plantain ash, insect pests

INTRODUCTION

Eggplant or garden-egg, *Solanum melongena* L. (Solanaceaea) variety *esculentum*, is an economically important vegetable crop in many Asian and African countries. The world wide production of eggplant has been reported to be 22.3 million metric tonnes annually with Asia producing 20.6 million metric tonnes, Africa 807.7 thousand metric tonnes, Europe 242.7 thousand metric tonnes, North and Central America 149.6 thousand metric tonnes, South America 5, 850 metric tonnes and Oceania 820 metric tonnes (Rajam *et al*., 2002). It has a wide variability in its morphological characteristics such as colour, shape and size, physiological attributes as well as biochemical features (Collonnier *et al*., 2001). Its fresh fruit weight is composed of 92.7% moisture, 1.4% protein, 1.3% fibre, 0.3% fat, 0.3% minerals (particularly iron) and the remaining 4% consists of vitamins A and C and various carbohydrates. Eggplant has been used in traditional medicines. For example, the alkaloid solanin extracted from the roots, leaves and fruits have been used for the treatment of asthma, bronchitis, cholera and dysuria fruits and leaves are beneficial in lowering blood cholesterol. In Nigeria, eggplants are usually eaten raw or can be chopped or sliced and fried or breaded in conjunction with similar prepared foods like tomatoes and oil bean. In some recipes the fruit is boiled and hollowed out and stuffed with various fish and meat dishes to be eaten with yam (Khan, 1979; Kalloo, 1993; Rajam *et al*., 2002).

Demand for year-round production of vegetables in many parts of the sub-Saharan Africa has resulted in a serious prevalence of pests and diseases of many crops. The insect pest complex of *S. melongena* includes; eggplant flea beetle, *Epitrix fuscula* (Crocht), the polyphagous fruit bollworm, *Helicoverpa armigera* (Hubner); the leaf hopper, *Empoasca flavescens*; the beetle, *Epilachna chrysomelina* (Thamb), cutworm, *Spodoptera littoralis* (Boisd), fruit and shoot borer, *Leucinodes orbonalis* (Guenee), whitefly, *Bemisia tabaci* (Genn), Colorado potato beetle, *Leptinotarsa decemlineata* (Say.), the polyphagous phloem-feeding aphids, *Myzus persicae* (Sulzer), *Aphis gossypii* (Glov.) and *Jacobiasca lybica* (de Berg) and spider mite, *Tetranychus ludeni* (Zacher) (Walter, 1999; Diaz *et al*., 2004; Cork *et al*., 2005). Seedling and fruited eggplants in Nigeria have a long history of being severely damaged by insect pests. Direct damage by these insect pests includes

Corresponding Author: D.A. Ukeh, Department of Zoology, University of Aberdeen, Tillydrone Avenue, AB24 2TZ, United Kingdom

stunting of shoots and leaves, shoot dieback, leaf or fruit deformation, distortion and skeletonisation. While indirect damages include transmission of phytopathogenic viruses, promotion of sooty mould on the leaves and enhancement of weather damage to the fruits (Ribeiro *et al.*, 2006). Currently, resource poor farmers rely almost entirely on synthetic pesticides for the control of pests and diseases of the crop. But the continuous application of synthetic pesticides has serious implications including acute and chronic poisoning of applicators, farm workers and even consumers, destruction of aquatic organisms, birds and other wildlife, disruption of natural biological control and pollination, extensive groundwater contamination, potentially threatening human and environmental health issues and the evolution of resistance to pesticides in pest populations (Singh *et al.*, 1991; Emosairue and Ukeh, 1996; Perry *et al.*, 1998; Abder-Rahman, 1999). Problems associated with the ineffectiveness of synthetic insecticides have become particularly acute in the production of eggplant (Cork *et al.*, 2003). However, there are insecticides of plant origin that are more environmentally friendly and devoid of adverse effects on the ecosystem that could be used against pests and diseases of eggplant in Nigeria. This alternative strategy aimed at decreasing the use of classical insecticides; sometimes referred to as ecochemical control based on plant-insect relationships has attracted research attention of late. Plant allelochemicals exert a wide range of effects on insects as repellents, deterrents or antifeedants. They may inhibit digestion, enhance pollination and capture with their attractive properties; they may increase oviposition or, contrarily, decrease reproduction by ovicidal and larvicidal effects. Most of these chemicals are secondary plant products and therefore have chemical structures that classify them as alkaloids, polyphenolics, terpenes and isoprenoids or cyanogenic glucosides (Regnault-Roger, 1997; Mordue *et al.*, 1998).

The objectives of this research work were to evaluate the field efficacies of plantain (*Musa sp.* AAB) inflorescence ash extract and neem (*Azadirachta indica* A. Juss) crude oil and seed extract for the control of insect pests associated with eggplant in Calabar, Nigeria.

MATERIALS AND METHODS

Experimental set up: Two field experiments were conducted between March and August 2005 at the University of Calabar Teaching and Research Farm of the Faculty of Agriculture (located within latitude 5°00′ and 5°40′ North and longitude 8°04′ and 8°62′ East). The total annual rainfall in this part of Nigeria ranges from 1500-3000 mm, humidity of 65-90% and temperatures of 22.2-38.2°C. Each experiment was laid out in pre-fallowed piece of land in a Randomised Complete Block Design (RCBD) consisting of 5 treatments with each treatment replicated five times as shown in Table 1. Each block measured 4×4 m and separated by paths of 1 m, the planting material with the trade name Yalon Bello was obtained from a seed company in France. The nursery was prepared on March 01, 2005 using mixture of components of garden soil, poultry droppings an sea sand in the ratio of 3:2:1 in local baskets. During seedbed preparation, properly cured poultry droppings were incorporated into the field at the rate of 5.3 tonnes per hectare (t ha^{-1}), as the crop requires much nutrient during this period of establishment. Seedlings were singly transplanted into the main field after 4 weeks in the nursery at a planting distance of 90 cm between rows and 75 cm within rows to give a plant population of 14, 167 stands ha^{-1}. A distance of 50 m separated the two experimental plots and both were weeded regularly throughout the duration of the field trials. An NPK 20.10.10 fertilizer was applied in split application of 400 kg per hectare 2 weeks after transplanting and during the onset of blossoming.

Preparation of plantain inflorescence ash extracts and neem products: Plantains are natural hybrids of two diploid species, *Musa acuminata* (Colla) and *Musa balbisiana* (Colla), which contributed the A and B genomes, respectively. Plantains originated in South East Asia but are so predominant in the humid lowlands of West and central Africa that this region is now considered as the secondary centre of diversification (Simmonds, 1995; Pillay *et al.*, 2003).

Fresh plantain inflorescence stalks from which the fruits have been removed were obtained from Akim Food stuff market in Calabar, Nigeria, sliced to small sizes and oven dried at 50°C for 24 h. The dried slices were burnt carefully, allowed to cool and sieved using 0.5 mm sieve (Endecott, England) to obtain a fine uniform ash texture that was stored in airtight container for use. To prepare 5% Plantain Ashes Extract (5% PAE), 50 g of the ash was weighed using electronic balance (Mettler Instrument AG, Zurich, Switzerland) and dissolved in 1000 cm^3 of deionised water for 12 h then filtered through nylon cloth. 4, 3 and 2% PAE were prepared using 40, 30 and 20 g of

Table 1: Treatment concentrations used for the experiments

Plantain ash extracts	Neem products
2% PAE	3% CNO
3% PAE	5% CNO
4% PAE	3% NSKE
5% PAE	5% NSKE
Untreated	Untreated

ash in 1000 cm^3 of deionised water, respectively. The neem tree, a Meliaceae, has long been recognised for its unique properties both against insects and improving human health. It is grown in most tropical and sub-tropical parts of the world for shade, reforestation and for the production of raw material for natural insecticides and medicines (Mordue and Nisbet, 2000). The 3 and 5% Crude Neem Products (CNO), 3 and 5% Neem Seed Kernel Extracts (NSKE) were formulated using the method adopted by Emosairue and Ukeh (1996).

Application of treatments and data collection: Application of plant products for the control of Insect pests of *S. melongena* commenced 2 weeks after transplanting and was maintained weekly to first harvesting. Treatments were applied in the morning and all plants were sprayed to runoff using a Knapsack sprayer. Assessment of pest infestation involved the weekly in situ examination of the plants, count of number and types of insects present in each block. The insects caught or observed were identified, classified and recorded separately. Other data obtained were the number of fresh fruits per plant, fruit weight and plant height at the last day of harvest. All data were collected from the two middle rows in all the blocks. Also, 10 fruits were randomly taken from each block after harvest, opened up with dissecting knife and assessed for the infestation of fruit-boring *Helicoverpa armigera* larvae. The data collected were subjected to the Analysis of Variance (ANOVA) and Tukey's pairwise comparison used to determine the difference between significant treatment effects using the on-line statistical software MINITAB version 14. Also, simple percentage was used to calculate the effects of plantain inflorescence stalk ashes and neem seed products on the prevalence of the pests.

RESULTS

The effects of plantain inflorescence ash and neem seed extracts on the prevalence of insect pests of *S. melongena* are presented in Table 2 and 3, respectively. The results showed that *Epilachna chrysomelina* was the most predominant insect pest, while *Z. variegatus* was the least observed insect in both trials. *E. chrysomelina* had the highest population abundance of 22 (23.8%) in the untreated plots, 12.6 (18.1%) in 2% PAE, 12 (26.8%) in 3% PAE, 7 (27.6%) in 4% PAE and 2.7 (28.4%) in 5% PAE, while Z. variegatus had 4.6 (4.9%) in the untreated, 3.5 (5%) in 2% PAE, 2 (4.5%) in 3% PAE, 1.2 (4.7%) in 4% PAE and 0.2 (2.1%) in 5% PAE, respectively (Table 2). *S. derogata* leaf rolling larvae, *E. fuscula* the flea beetle, *A. gossypii* and *H. armigera* were generally relatively prevalent in decreasing order. In terms of efficacy on pest populations, the ranking of plantain inflorescence ash was as 5% PAE > 4% PAE>3% PAE >2% PAE (Table 2). In the neem seed products treated plots, *E. chrysomelina* population per plant was 4.2 (20.8%) in 3% CNO, 2.7 (30.7%) in 5% CNO, 4.8 (20.3%) in 3% NSKE, 2.4 (25%) in 5% NSKE and 6.8 (18.2%) in the untreated plots. *A. gossypii* seemed to be very sensitive to neem products as the concentration increases because it had a mean number of 11.3 (30.2%) in the untreated, 32. (15.8%) in 3% CNO, 5.6 (23.7%) in 3% NSKE, 1.1 (11.4%) in 5% NSKE and 0.6 (6.8%) in 5% CNO treated plots, respectively (Table 3). We also observed that the neem seed product which conferred the best protection to *S. melongena* against insect pests was 5% CNO with the mean number of 8.8 pests, followed by 5% NSKE (9.6), 3% CNO (20.2) and 3% NSKE (23.6) insect pests, respectively.

In the plantain ash extracts treated plots, there were significant differences ($F_{4,}$ 24 = 24.63; p<0.001) in the mean fresh fruits weight (kg) and ($F_{4,}$ 24 = 20.86; p<0.001)

Table 2: Effect of plantain ash on the percentage prevalence of insect pests associated with *S. melongena* per plant

Treatments	Type of insects	No. of insects	Prevalence (%)
2% PAE	*Epilachna chrysomelina*	12.6	18.1
	Sylepta derogata	13	18.7
	Helicoverpa armigera	14	20.1
	Zonocerus variegatus	3.5	5
	Epitrix fuscula	11.5	16.5
	Aphis gossypii	15	21.6
	Sub-total	69.6	
3% PAE	*Epilachna chrysomelina*	12	26.8
	Sylepta derogata	5.4	12.1
	Helicoverpa armigera	8	17.9
	Zonocerus variegatus	2	4.5
	Epitrix fuscula	8	17.9
	Aphis gossypii	9.4	20.9
	Sub-total	44.8	
4% PAE	*Epilachna chrysomelina*	7	27.6
	Sylepta derogata	3.6	14.2
	Helicoverpa armigera	3.3	13
	Zonocerus variegatus	1.2	4.7
	Epitrix fuscula	4.3	16.9
	Aphis gossypii	6	23.6
	Sub-total	25.4	
5% PAE	*Epilachna chrysomelina*	2.7	28.4
	Sylepta derogata	1.8	18.9
	Helicoverpa armigera	1.5	15.8
	Zonocerus variegatus	0.2	2.1
	Epitrix fuscula	2.2	23.2
	Aphis gossypii	1.1	11.6
	Sub-total	9.5	
Untreated	*Epilachna chrysomelina*	22	23.8
	Sylepta derogata	14.6	15.8
	Helicoverpa armigera	17	18.4
	Zonocerus variegatus	4.6	4.9
	Epitrix fuscula	13.2	14.3
	Aphis gossypii	21.2	22.9
	Sub-total	92.6	
	Total	241.9	

Table 3: Effect of neem seed products on the percentage prevalence of insectpests of *S. melongena* per plant

Treatments	Type of insects	No. of insects	Prevalence (%)
3% CNO	*Epilachna chrysomelina*	4.2	20.8
	Sylepta derogata	2.8	13.9
	Helicoverpa armigera	4.3	21.3
	Zonocerus variegatus	2.6	12.9
	Epitrix fuscula	3.1	15.3
	Aphis gossypii	3.2	15.8
	Sub-total	20.2	
5% CNO	*Epilachna chrysomelina*	2.7	30.7
	Sylepta derogata	1.5	17
	Helicoverpa armigera	2.2	25
	Zonocerus variegatus	0.4	4.6
	Epitrix fuscula	1.4	15.9
	Aphis gossypii	0.6	6.8
	Sub-total	8.8	
3% NSKE	*Epilachna chrysomelina*	4.8	20.3
	Sylepta derogata	3.3	14
	Helicoverpa armigera	4.9	20.8
	Zonocerus variegatus	2.3	9.7
	Epitrix fuscula	2.7	11.4
	Aphis gossypii	5.6	23.7
	Sub-total	23.6	
5% NSKE	*Epilachna chrysomelina*	2.4	25
	Sylepta derogata	2.1	21.9
	Helicoverpa armigera	1.8	18.8
	Zonocerus variegatus	0.5	5.2
	Epitrix fuscula	1.7	17.7
	Aphis gossypii	1.1	11.4
	Sub-total	9.6	
Untreated	*Epilachna chrysomelina*	6.8	18.2
	Sylepta derogata	4.7	12.6
	Helicoverpa armigera	5.1	13.6
	Zonocerus variegatus	3.9	10.4
	Epitrix fuscula	5.6	15
	Aphis gossypii	11.3	30.2
	Sub-total	37.4	100
	Total	99.6	

and number of fruits per plant between the treated and the untreated plots (Table 4). Treatments with the best yield was 5% PAE which had 2.28 kg of fresh fruit weight and 23.2 fruits per plant, while the least yield was recorded in the 2% PAE treated plots with 0.9 kg fresh fruit weight and 11.8 fruits of *S. melongena* per plant, respectively. However, there were no significant differences ($p<0.05$) among the various plant-derived insecticides in the final plant heights (Table 4 and 5). Similarly, yield was significantly increased in the neem products-treated plots of S. *melongena* plants than the untreated plots (Table 5). There were significant differences ($F_{4,}$ 24 = 22.7; $p<0.001$) in the fresh fruit weight and ($F_{4,}$ 24 = 14.77; $p<0.001$) number of fruits per plant when neem oil and seed extracts were applied to the growing plants. 5% CNO had the highest mean fruit weight of 1.78 kg, followed by 5% NSKE with 1.76 kg, 3% NSKE 1.44 kg and 3% CNO 1 kg per plant, respectively. For the mean number of fruits per plant, 5% NSKE treated plots recorded the highest number of 24.6, 5% CNO 24, 3% NSKE 19.8 and 3% CNO 16 fruits. However, no significant differences ($p<0.05$) were observed between 2% PAE and the untreated plot (Table 4) and 3% CNO and the untreated plots in fruit weights and number of fruits per plant (Table 5).

Table 4: Mean yield and yield related parameters per plant in the plantain ash treated plots

Treatments	Fresh fruits weight (Kg)	Number of fruits	Plant height (cm)
2% PAE	0.9±0.15[c]	11.8±0.72[b]	99.4±1.29[a]
3% PAE	1.8± 0.19[b]	13.4± 0.48[b]	95.4±1.22[a]
4% PAE	1.92±0.19[b]	21.4±0.68[a]	96.2±1.03[a]
5% PAE	2.28±0.32[a]	23.2±0.97[a]	100.8±0.95[a]
Untreated	0.94±0.21[c]	10.6±0.68[b]	97.8±1.53[a]

*Means within a column followed by the same letter superscript are not significantly different ($p<0.05$)

Table 5: Mean yield and yield related parameters per plant in the neem products treated plots

Treatments	Fresh fruits weight (Kg)	Number of fruits	Plant height (cm)
3% CNO	1.0±0.14[b]	16±0.56[b]	98.8±0.84[a]
5% CNO	1.78±0.04[a]	24±0.9[a]	98±1.06[a]
3% NSKE	1.44±0.15[ab]	19.8±0.75[ab]	99±0.93[a]
5% NSKE	1.76±0.23[a]	24.6±0.94[a]	100.8±0.93[a]
Untreated	0.9±0.21[b]	12±0.56[b]	97.2±1.49[a]

*Means within a column followed by the same letter superscript are not significantly different ($p<0.05$)

DISCUSSION

The results of this research work indicate that plantain inflorescence ash extracts and neem seed products (oil and water extracts) could reduce the infestation of insect pests and improve the yield of eggplant. During the research work, it was observed that insects could be grouped into foliage feeders, primarily Coleopteran insects (*E. chrysomelina* and *E. fuscula*) and caterpillars that attack leaves and fruits such ads *H. armigera* and *S. derogata*. *S. derogata* larvae rolls the leaves, fold them and feed extensively on them forming webs resulting to leaf and flower abscission and yield and quality reduction. Although eggplant has a high growth rate, large populations of these insects can retard growth, reduce yield and kill the crop (Hill, 1983; McLeod *et al*., 2002). *E. chrysomelina* is a major pest whose larvae and adults feed on the leaves of eggplants by scrapping the surface and reducing the leaves to skeletons when infestation is high. The adult looks like a typical ladybird but has the distinction of being the only phytophagous representative of this family (Hill, 1983). *E. fuscula* migrate and feed on young eggplant seedlings soon after transplanting into the main field and the resulting damage is a short-hole appearance of the leaves. It has also been indicated as a vector of eggplant mosaic virus (Sorenson and Baker 1994; McLeod *et al*., 2002).

The application of bio-pesticides that offer desirable alternatives to using synthetic chemicals in agricultural systems where protection of the environment and preservation of beneficial organisms are paramount has increased in recent years. Although, there have been little or no attempt so far to control insect pests of eggplant using plantain inflorescence ash extracts, much attention has been shifted to the neem tree. The suppression or repellence of insect pests of eggplants by plantain inflorescence ash extracts could be the antifeedants effect of the alkaline content in the ash as shown in Table 2 and 4. But crude formulations of neem seed extracts contain azadirachtin, a complex tetranortriterpenoid liminoid and other liminoids that contribute to insecticidal properties (Mordue and Blackwell, 1993). The diverse effects of azadirachtin on insect pests include feeding deterrence, reproduction disturbance and insect growth regulation. Furthermore, the compound has minimal toxicity to nontarget organisms such as pollinators, predators and parasitoids thereby increasing its acceptability for the management of phytophagous pests (Naumann and Isman, 1996; Emosairue and Ukeh, 1996; Walter, 1999; Mordue and Nisbet, 2000; Weathersbee and Tang, 2002; Isman, 2002). The antifeedants effects observed by the insect pests during these field trials correlated with the sensory response of chemoreceptors on the insect mouthparts (Mordue *et al*., 1998). Insect feeding behaviour depends upon both neural inputs from their chemical senses such as taste receptor on the tarsi, mouthparts and oral cavity and central nervous integration of this sensory code. Bio-pesticides stimulate specific deterrent cells in chemoreceptors and block the firing of sugar receptor cells, which normally stimulate feeding. This results to starvation and death of these pest species by feeding deterrency (Mordue and Nisbet, 2000; Isman, 2006). Similar results reported by Schulthess *et al*. (2006) showed that the injection of azadirachtin in litchi trees, *Litchi chinensis* resulted in the inhibition of ecdysis, antifeedancy and mortality of the litchi stink bug, *Tessaratoma papillosa* Drury in northern Thailand. Also, neem products had satisfactory antifeedancy on the gypsy moth, *Lymantria dispar* L. and the Colorado potato beetle, *Leptinotarsa decemlineata* larvae in the laboratory and field experiments (Zabel *et al*., 2002). More recently, the drimane dialdehydes polygodial, first isolated from the water pepper, *Polygonum hydropiper* and warburganal, isolated from *Warburgia ugandensis* are reported to exhibit repellent activity against a wide range of agricultural and domestic pests (Messchendorp *et al*., 1998, 2000; Cook *et al*., 2007).

CONCLUSION

The main objective of these field trials was to evaluate the effects of plantain inflorescence ash extract and neem seed oil and water extracts on the pests and yield of *S. melongena*. Results showed that both plant products reduced the pests' infestation and improved crop yields probably they evoked non-host avoidance and repellent behaviours. Summarily, 5% PAE, 5% NSKE and 5% CNO offered the best protection of the crop against insect pests and increased crop yields. However, although these bio-pesticides are relatively non-toxic and safe to humans and ecosystem, the duration of their effects under tropical field condition is often limited.

REFERENCES

Abder-Rahman, H., 1999. Effect of aluminium phosphide on blood glucose level. Vet. Human Toxicol., 41: 31-32.

Collonnier, C., I. Fock, V. Kashyap, G.L. Rotino, M.C. Daunay, Y. Lian, I.K. Mariska, M.V. Rajam, A. Servaes, G. Ducreux and D. Sihachakr, 2001. Applications of biotechnology in eggplant. Plant Cell Tissue and Organ Cult., 65: 91-107.

Cook, S.M., Z.R. Khan and J.A. Pickett, 2007. The use of Push-Pull strategies. In: Integrated Pest Management. Ann. Rev. Entomol., 52: 365-400.

Cork, A., S.N. Alam, F.M.A. Rouf and N.S. Talekar, 2003. Female sex pheromone of brinjal fruit and shoot borer, *Leucinodes orbonalis*: Trap optimization and application in IPM trials. Bull. Entomol. Res., 93: 107-113.

Cork, A., S.N. Alam, F.M.A. Rouf and N.S. Talekar, 2005. Development of mass trapping technique for the control of brinjal shoot and fruit borer, *Leucinodes orbonalis* (Lepidoptera: Pyralidae). Bull. Entomol. Res., 95: 589-596.

Diaz, F.J., P.J. McLeod and D.T. Johnson, 2004. Seasonal occurrence and distribution of eggplant flea beetle, *Epitrix fusca* Crocht Coleoptera: Chrysomelidae) on eggplant in Arkansas. J. Kansas Entomol. Soc., 77: 80-88.

Emosairue, S.O. and D.A. Ukeh, 1996. Field trial of neem products for the control of Okra flea beetles (*Podagrica* sp.) in South Eastern Nigeria. Af. J. Plant Prot., 37: 22-26.

Hill, S., 1983. Agricultural insect pests of the tropics and their control (2nd Edn.), Cambridge University Press, Cambridge.

Isman, M.B., 2002. Insect antifeedants. Pestic. Outlook, 13: 152-157.

Isman, M.B., 2006. Botanical Insecticides, Deterrents and Repellents in Modern Agriculture and an increasingly regulated World. Ann. Rev. Entomol., 51: 45-66.

Kalloo, G., 1993. Eggplant (*Solanum melongena*). In: Kalloo, G. (Ed.), Genetic improvement of vegetable crops. Pengamon Press Oxford, pp: 587-604.

Khan, R., 1979. *Solanum melongena* and its Ancestral Forms. In: Hawkes, J., Lester, R.N., Skelding, A.D. (Eds.), The biology and Taxonomy of Solanaceae. Academic Press, London, pp: 629-636.

McLeod, P., F.J. Diaz and D.T. Johnson, 2002. Toxicity, persistence and efficacy of spinosad, chlorfenapyr and thiamethoxam on eggplant when applied against the eggplant flea beetle Coleoptera: Chrysomelidae. Hort. Entomol., 95: 331-335.

Messchendorp, L., G.J.Z. Gols and J.J.A. Van Loon, 1998. Behavioural effects and sensory detection of drimane deterrents. In: *Myzus persicae* and *Aphis gossypii* nymphs. J. Chem. Ecol., 24: 1433-1446.

Messchendorp, L., G.J.Z. Gols and Van Loon, 2000. Behavioural observations of *Pieris brassicae* larvae indicate multiple mechanisms of action of analogous drimane antifeedants. Entomol. Exp. Applied, 95: 217-227.

Mordue Luntz, A.J. and A. Blackwell, 1993. Azadirachtin: An update. J. Insect Physiol., 39: 903-924.

Mordue Luntz, A.J. and A. Nisbet, 2000. Azadirachtin from the Neem tree *Azadirachta indica*: Its action against insects. Ann. Soc. Entomol. Brasil, 29: 615-632.

Mordue Luntz, A.J., M.S.J. Simmonds, S.V. Ley, W.M. Blaney, W. Mordue, M. Nasiruddin and A.J. Nisbet, 1998. Actions of Azadirachtin, a plant allelochemical against insects. Pesticide Sci., 54: 277-284.

Perry, A.S., I. Yamamoto, I. Ishaaya and R.Y. Perry, 1998. Insecticides in Agriculture and Environment: Retrospects and Prospects. Springer-Verlag, Berlin. Isman, M.B., 2002. Insect antifeedants. Pestic. Outlook, 13: 152-157.

Pillay, M., G. Ude, E. Ogundiwin and A. Tenkouano, 2003. Genetic diversity in an African plantain core collection using AFLP and RAPD markers. Theor. Applied Genet., 107: 248-255.

Rajam, M.V., V. Kashyap, S. Vinod Kumar, C. Collonnier, R. Haicour, G.L. Rotino and D. Sihachakr, 2002. Biotechnology of eggplant. Scientia Horticult., 97: 1-25.

Regnault-Roger, C., 1997. The potential of botanical essential oils for insect pest control. Integrated Pest Manage. Rev., 2: 25-34.

Ribeiro, A.P.O., E.J.G. Pereira, T.L. Galvan, M.C. Picanco, E.A.T. Picolo, D.J.H. Da Silva, M.G. Fari and W.C. Otoni, 2006. Effect of eggplant transformed with *oryzacystatin* gene on *Myzus persicae* and *Macrosiphum euphorbiae*. J. Applied Entomol., 1302: 84-90.

Schulthess, M.J., K. Martin and J. Sauerborn, 2006. Effects of Azadirachtin injection in litchi trees *Litchi chinensis* Sonn on the litchi stink bug *Tessaratoma papillosa* Drury in northern Thailand. J. Pestic. Sci., 79: 241-250.

Simmonds, N.W., 1995. Bananas: *Musa* Musaceae. In: J. Smartt, N.W. Simmonds, Eds. Evolution of crop plants (2nd Edn.), Longman Scientific and Technical, Harlow, UK.

Singh, R.B., R.G. Singh and U. Singh, 1991. Hypermagnesemia following aluminium phosphide poisoning. Int. J. Clin. Pharmacol., 29: 82-85.

Sorenson, K.A. and J.R. Baker, 1994. Insect and related pests of vegetables. N.C. Coop. Ext. Serv, Releigh.

Walter, J.F., 1999. Commercial Experience with Neem Products. In: F.R. Hall and J.J. Menn (Eds.), Biopesticides: Use and delivery. Humana, Totowa, New Jersey.

Weathersbee, A.A. and Y.Q. Tang, 2002. Effect of neem seed extract on feeding, growth, survival and reproduction of *Diaprepes abbreviatus* Coleoptera: Curculionidae. J. Econ. Entomol., 95: 661-667.

Zabel, A., B. Manojlovic, S. Rajkovic, S. Stankovic and M. Kostic, 2002. Effect of neem extract on *Lymantria dispar* L. Lepidoptera: Chrysomelidae. J. Pest. Sci., 75: 19-25.