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Research Article

Calneem: A commercial neem seed-based biopesticide for sustainable management of pests of vegetables in Ghana

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Abstract
The production of vegetable crops is a major agricultural activity of small and medium-scale farmers in Ghana and has a great potential to increase the income levels growers. However, vegetable production is constrained among other factors by attack by insect pests, diseases, nematodes and the declining soil fertility, necessitating the use of pesticides and artificial fertilizers. Currently, the main method of controlling pests and diseases of vegetable crops is the use of synthetic pesticides. This paper examines the environmental, food safety, health and other problems inherent in the dependency on conventional pesticides to control crop pests in Ghana and advocates the need to develop a sustainable and environmentally sound alternative pest management strategy using neem pesticides as the major component. Native to India and Burma, the neem tree, *Azadirachata indica A*. Juss was introduced to Africa earlier this century and is now well established in at least 78 countries, including Ghana where it has become an important source of fuel, lumber and biopesticides. Neem products are broad spectrum bio-pesticides which are effective against several pests of vegetables, food crops, fruit and other tree crops. Using the results of extensive field trials conducted in two locations in the Greater Accra Region of Ghana, the paper would demonstrate the practical utilization of Calneem oil and Neem seed extract for sustainable protection of okra and cucumber against pest infestation in Ghana. It would also show that neem pesticides are less harmful to some beneficial organisms in the vegetable agro-ecosystem such as certain ant species, lady bird beetles, dragon flies and other predators. Practical challenges to widespread application of neem bio-pesticides for sustainable crop protection in Ghana are discussed.

Keywords
Arthropod pests—Calneem—cucumber—okra—bio-pesticide–neem seed extract—Callidim

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Contents

1. Introduction

The production of vegetable crops is a major all-year-round agricultural activity of small-scale farmers in Ghana and has a great potential to increase the income level and standard of living of growers (Afreh-Nuamah, 1996; Obeng-Ofori and Ankra, 2002). Okra and cucumber are important source of nutrients in the diet of most families in Ghana and are therefore cultivated extensively in the country (Sinnadurai, 1992; Norman, 1992). One major constraint to the cultivation of vegetables in Ghana is the incidence of arthropod pests and diseases. For a long time, farmers had relied heavily on the use of synthetic pesticides to combat the numerous pests and diseases that attack the crops. Apart from the ever-increasing costs of these chemicals, they are known to have negative impacts on the environment. They destroy the natural environment and leave residues in food, which become toxic to humans. Furthermore, most of the commonly used pesticides are now less effective because the target pests have developed resistance. This therefore calls for the development of integrated pest management system that would make minimal and selective use of synthetic pesticides. One important component of IPM system is the use of biopesticides especially those derived from plants (Schmutterer, 1985; Jackai and Oyediran, 1991; Ken et al., 1994; Schmutterer and Hellpap, 1995; Youdeowei, 2000; Akakpo et al., 2001; Obeng-Ofori and Kelly, 2001; Obeng-Ofori and Ankrah, 2002; Obeng-Ofori and

Sackey, 2003; Adjei-Nsiah et al., 2003; Owusu-Ansah et al., 2003; Obeng-Ofori, 2010; 2011).

Native to India and Burma, the neem tree, *Azadirachata indica A.* Juss is a member of the mahogany family, Meliaceae. It was introduced to Africa earlier this century (Schmutterer and Hellpap, 1995; Foster, 2000). It is now well established in at least 30 countries, including Ghana where it has become an important source of both fuel and lumber. It grows in many parts of Ghana (Cobbina and Osei-Wusu, 1988). Neem contains several active ingredients (at least nine limonoids, including azadirachtin, meliantriol, salamin, nimbin and nimbidin), and they act in different ways under different circumstances (Schnntterer, 1985; 1990). Neem products are broad spectrum in activity and are known to affect over 200 species of insects, as well as some mites, nematodes, fungi, bacteria and even a few viruses (Schmutterer, 1985). They have insecticidal, repellent, antifeedant, sterilizing and growth inhibition effects (Schmutterer, 1990; Ken et al., 1994). Although, they attack many pest species, neem products are harmless to mammals and beneficial insects, are biodegradable and appear less likely to build up genetic resistance in target pests.

Calneem is pure and natural oil extracted from hand selected high quality neem seeds. It is produced and marketed in Ghana by AQUA AGRIC Community Projects (AACP), Accra. It is a broad spectrum insecticide which is effective against several pests of vegetables, food crops, fruit and other tree crops. Crude neem seed extract was prepared from ripened and fallen seeds with water. Callidim 400 EC (diamethioate) is a synthetic organophosphate and broad spectrum insecticide recommended for the control of insect pests of vegetables and food crops.

In this study, the biological efficacy of calneem and crude neem seed extract were compared with callidim (diamethoate) against major pests of okra and cucumber (poinsette variety) and okra (Legon spineless variety). The effect of the products on some beneficial organisms in the cucumber and okra ecosystems was also assessed.

1.1 Materials and Methods

Field experiments were carried out to assess the biological efficacy of Calneem and 'home made' neem seed extract against arthropod pests of okra, tomato, cabbage and cucumber at the Ashiaman Irrigation Site and the University farm, Legon.

1.1.1 Insecticide Products Tested

Calneem oil is produced and marketed in Ghana by AQUA AGRIC Community Projects (AACP), Accra. It is an in-house prepared, cold pressed, double filtered, pure and natural oil derived from hand selected high quality neem seeds. The oil was extracted from neem seeds that were thoroughly washed, depulped, dehulled, shade dried and completely free from solvent and synthetic material. Calneem contains about 0.3% azadirachtin as its major active ingredient. It is a broad spectrum insecticide which is effective against several pests of vegetables, food crops, fruit and other tree crops. Some of the major target pests are aphids, mealybugs, plant bugs, grasshoppers, flea beetles, leaf miners, spider mites, fruit flies, diamondback moth and several leaf eating caterpillars. To prepare the 10 litres of Calneem oil spray solution, 50 ml of the Calneem oil was mixed with 10 ml of liquid soap as emulsifier. This was then added to 10 litres of water, mixed thoroughly before spraying

- Crude Neem Seed Extract was prepared by collecting neem seeds from the neem tree, removing the pulp from ripened seeds and pounding the kernels in a mortar into powder. It was mixed with water and kept overnight. It was filtered through a fine cloth to obtain the filtrate which was applied at the rate of 50 g/litre of water.
- Callidim 400 EC with diamethoate as the active ingredient is a synthetic organophosphate and broad spectrum insecticide recommended for the control of insect pests of vegetables and food crops. It was applied at the rate of 2 ml/littre of water.

1.2 Field Layout and Planting of Okra

This field trial was conducted at the Ashiaman Irrigation Site which has a humid tropical climate and the soil type is "Bumbi" series. It is an experimental site, where experiments of different scales and complexity, and involving various vegetables and food crops are conducted throughout the year. Insect pest infestation is high at the site due to the large farm size, weed problems and continuous cultivation all-year round.

Okra was planted in the major and minor seasons in 2010 and 2011 (March-July and September–December, respectively). The land was prepared by ploughing, harrowing and pegging. Plots measured 4.8 m by 3.2 m and were separated by 1.0 m alleys. Okra seeds were planted at three seeds per hill and thinned to one plant per hill after germination. Plants were spaced 0.6 m by 0.3 m with four rows per plot and 10 plants per row. NPK (15-15-15) fertilizer was applied at the rate of 250 kg/ha after the establishment of the plants on the field and was followed with sulphate of ammonia at the rate of 175 kg/ha. The plots were arranged in a randomized complete block design with four replicates and four treatment plots in a block (i.e. Calneem oil, crude neem seed extract, Callidim 400 EC and non-insecticide control). Weeds were controlled using hand weeding and all other agronomic practices were carried out when necessary.

1.3 Field Layout and Planting of Cucumber

The experiment was conducted at the University of Ghana Farm, Legon, in the major and minor rainy seasons in 2010 and 2011. The soil is the Adenta series and belongs to the Entic Nitosol (FAO/UNESCO Classification). The vegetation is coastal savannah and has a mean annual rainfall of 112 mm. An area 17.4 m x 12 m (208.8 m2) was used for the experiment and the design was Randomized Complete Block Design. Cucumber seeds (Poinsette variety) were planted at stake at a distance of 120 cm x 75 cm. Three seeds were planted per hill and later thinned to two. Compound fertilizer NPK 15:15:15 was applied at 7.5 g per plant at planting and were buried 3-4 cm from the plant and top-dressed with 2.5 g sulphate of ammonia per plant four weeks after planting. Weeds were controlled by hoeing.

1.4 Application of Insecticides

In all the field experiments, the treatments evaluated were 5.0 ml of Calneem oil in 1.0 ml detergent as emulsifier, 50 g neem seed/litre of water, 2.0 ml of Callidim 40 EC/litre of water as standard reference product and control (water only). All the insecticides were applied on the plants using a calibrated knapsack (CP15) sprayer delivering at an application rate of 200 l/ha. The insecticides were first applied when pests started damaging the leaves of the vegetable plants, and subsequently repeated every 10-14 days until fruit maturity. In all there were four insecticide applications per cropping season. The abundance of insects in each plot was assessed before and two days after insecticide application.

1.5 Data Collection and Analysis

Insect fauna on okra and cucumber plants was first assessed before insecticide application and subsequently two days after the application of insecticides. The plants were critically observed and insect found on them were collected by hand-picking, use of aspirators, sweep nets or yellow traps as appropriate depending on the type of insects. Records were taken on the six tagged middle plants in each row. All trapped insects were sent to the laboratory for identification. Data collected included insect fauna on okra plants, insect population density in the various treatments, and percent leaf and fruit damage caused by the insect pests. The number, weight, length and width of the harvested fruits were also recorded. The final fruit yield in kg/ha for each treatment was estimated.

Data collected in the minor and major seasons were pooled, transformed and then analysed using analysis of variance (ANOVA) package in StatView for Windows v. 5.0.1 (SAS Institute Inc. Cary, NC, USA) at 0.05 α level. Where significant differences were obtained, the means were separated with LSD test at 5% level of significance.

2. Results

2.1 Insect Fauna on Okra

The list of insects encountered on okra ecosystem during the sampling period is shown in Table 1. The insects were in the orders Coleoptera, Heteroptera, Homoptera, Lepidoptera, Orthoptera and Odonata, Different stages of the insect pests attacked various parts of the crop causing varying degrees of damage. Among these, the major insect pests found included the cotton aphids, cotton mealy bugs, white flies, flea beetles, epilachna beetles, cotton stainers and variegated grasshoppers. Others were leafhoppers, boll worms and leaf rollers. The beneficial insects were ladybird beetles, dragon flies and several species of predatory bugs and beetles. Table 2 shows the effect of the treatments on the numbers of some of the major insect pests collected on okra. The numbers of A gossypii, B. tabaci, Empoasca spp., P. hirsutus, H. armigera, Dysdercus spp., Sylepta derogata and P. uniformis were significantly ($P<0.05$) higher on the control plots than the insecticide treated plots (Table 2). Calneeem oil, neem seed extract (NSE) and callidim 400 EC caused significant reduction in the numbers of the major pests on okra plants. The control plants recorded the highest number of pests while very low numbers of insect pests were recorded on the plants treated with Calneem oil, crude neem seed extract or synthetic callidim 400 EC insecticide. Comparing the insecticide treated plots, callidim 400 EC recorded the least numbers of the various major pests attacking okra followed by Calneem oil treated plots.

Table 3 shows the effect of the different insecticides on the beneficial insects encountered during the experiments. Callidim 400 EC treated plots recorded the least number of all the beneficial insects compared to the neem insecticides. The control recorded the highest number of each beneficial insect collected. Generally, the effects of the neem insecticides (Calneem oil and neem seed extract) on the beneficial insects were not significantly ($P<0.05$) different from each other. However, they differed significantly ($P<0.05$) from the synthetic insecticide (Callidim 400 EC).

Table 1. Insect fauna associated with okra at Ashaiman Irrigation site, Accra, Ghana

Coleoptera	Family	Activity
**Podagrica uniformis Jac.*	Halticidae	Adult feeds on leaves
**Epilachna similis Rossi.*	Coccinelidae	Adult feeds on leaves and fruits
**Podagrica bowringi Baly.*	Halticidae	Adult feeds on leaves
#*Cheilomenes vicinia Muls.*	,,	Adult feeds on Aphids
#*Cheilomenes lunata F.*	,,	Adult feeds on Aphids
#*Bachyplatus spp.*	,,	Adult feeds on Aphids
Heteroptera		
**Dysdercus superstitiosus (F.)*	Pyrrhocoridae	Adults and nymphs suck sap from fruits
#Rhinocoris spp.	Reduvidae	Feeds on other bugs and beetles
Homoptera		
**Aphis gossipii Glov.*	Aphididae	Sucks sap from underside of leaves
**Phenacoccus hirsutus Green*	Pseudococcidae	Sucks sap from leaves and tender fruits
**Empoasca spp.*	Cicadelidae	Sucks sap from underside of older leaves
Diptera		
**Bemisia tabaci (Genn)*	Aleyroidae	Sucks sap from underside of older leaves
Lepidoptera		
**Heliothis armigera Hb.*	,,	Larva feeds and bores into fruits
**Sylepta derogata (F.)*	Pyralidae	Larva rolls leaves and feeds on leaf lamina
Orthoptera		
**Zonocerus variegatus (L.)*	Pyrgomorphidae	Adults and nymphs feed on leaves
Odonata		
#*Odonata spp.*		Feeds on several insect pests

* Major insect pests; # Beneficial insects

Table 2. Abundance of the major insect pests on okra plants treated with different insecticides at the Ashiaman Irigation Site, Accra, Ghana

	Mean Number of Insects			
Major Insect pests	Neem seed extract	Calneem oil	Callidim	Control
Aphis gossypii	33.6	30.5	30.15	180.5
Bemisia tabaci	34.08	30.3	35.05	178.5
Empoasca spp.	20.45	18.65	10.6	104.42
			9.95	109.55
Phenacoccus hirsutus	24.78	20.2		
Heliothis armigera	26.3	20.85	8.45	95.45
Dysdercus spp.	8.73	5.08	3.35	43.25
Sylepta derogata	22.68	15.78	5.85	86.88
Podagrica uniformis	12.55	10.3	10	135.13
LSD (P<0.05) 10.2				

Table 3. Abundance of beneficial insects on okra ecosystem treated with different insecticides at the Ashiaman Irrigation Site, Accra, Ghana

Beneficial insects	Mean Number of Insects			
	Neem seed extract	Calneem oil	Callidim	Control
Cheilomenes vicinia	16.75	15.7	1.43	39.68
Cheilomenes lunatus	30.35	34.13	3.78	46.93
Rhinocoris spp.	14.05	18.48	2.83	37.45
Rhinocoris rapax	27.43	30.55	1.98	32.6
Coccinella spp.	27.95	30.23	1.05	37.68
Odonata spp.	34.48	36.78	1.2	37.83
Bachyplatus spp.	24.68	25.65	1.13	32.13
LSD (P<0.05) 5.5				

2.2 Insect Pest Damage and Yield of Okra

Table 4 shows the percentage leaf damage caused by various phytophagous insect pests and fruit damage caused by fruit borers in each treatment. Leaf damage was significantly higher ($p<0.05$) in the control plants compared to plants that were treated with Calneem oil, Neem seed extract or Callidim 400 EC. The leaves of untreated control plants were significantly ($P< 0.05$) heavily damaged compared to the insecticide treated plants. Callidim 400 EC and the neem insecticides were equally effective in reducing damage caused by leaf feeders. Similarly, fruit damage caused by fruit borers was reduced significantly by the insecticide treatments (Table 4). Significant differences did not occur among the insecticide treatments. The control produced the highest percentage of bored fruits compared with Cillidim, Calneem oil or Neem seed extract treated plots. Callidim produced the least number of damaged fruits, followed by Calneem oil and Neem extract in that order.

There was significant difference among the treatments in fresh fruit yield (Table 4). Plots treated with insecticides produced larger number of fresh fruits and higher yield than untreated control plots. Among the insecticide treatments, the fruit yield from plots treated with Callidim, Neem seed extract or Calneem oil was not significantly ($P<0.05$) different from each other.

Table 4. Leaf and fruit damage caused by insect pests and the resultant fruit yield of okra treated with different insecticides at the Ashiaman Irrigation Site, Accra, Ghana

Treatments	%leaf damage	%fruit damage	Yield (kg/ha)
Crude neem extract	5.5	9.1	3,640
Calneem oil	5.2	8.5	3,660
Callidim 400 EC	3.5	6.6	3,750
Control	34.3	45.3	2,395
LSD (P<0.05)	5.4	5.8	350

2.3 Insect Fauna and Yield of Cucumber

Insects found associated with cucumber at the University of Ghana Farm and their abundance are shown in Table 5. Twenty one different insect species were collected on cucumber but the major pests were the epilachna beetle, cucumber beetle, cucurbit leaf beetle, aphid, melon fruit fly and the pollen beetle. Others were cotton stainer, Assin bug, several species of grasshoppers, melon worm moth, psyllid, Lagria beetle and the African mole cricket. Some beneficial insects including wasps, ladybird beetles, techinid flies and honey bees were also recorded. The highest number of insects was recorded on the control plot followed by neem seed extract (NSE), Calneem oil and lastly callidim 400 EC (Table 6). The important leaf feeding insects found included the epilachna beetle, cucumber beetle, aphids and cucurbit leaf beetle. The important pests that attacked the fruits were the melon fruits fly, psyllids, melon worm moth and Assasin bugs (Table 6). All the insecticides tested significantly reduced the numbers of these insects on the plants compared to the control plants (Table 6). Consequently, leaf and fruit damage was higher on control plants compared to insecticide treated plants (Table 6).

The mean number of fruits per plant, mean fruit weight, fruit length and width recorded in the different treatments are shown in Table 7. In all these parameters there were significant (P<0.05) differences among the treatments. Plants treated with Calneem oil, Neem seed extract and Callidim 400 EC did not differ significantly from each other for these yield parameters. Plots treated with Calneem oil, Neem seed extract and Callidim recorded significantly (P<0.05) higher number of fruits harvested per plot than the plants in the control plots. Fruit yield per hectare was equal among the three insecticides but was significantly higher than the control plots (Table 7).

Table 5. Insect fauna collected on cucumber at the University Farm Legon, Ghana

Common Name	Scientific Name	Order	Economic Importance
Pollen beetle	*Coryna spp.*	Coleoptera	Feed on flowers
Epilachna beetle	*Epolachna similis Rossi*	Coleoptera	Feed on leaves and fruits
Cucumber beetle	*Acalyma vittatum Fabricius*	Coleoptera	Feed on young seedlings, leaves, roots and fruits
Lagria beetle	*Lagria cuprina* (Thomas)	Coleoptera	Feed on leaves and fruits
Cucurbit leaf beetle	*Aulacophora spp.*	Coleoptera	Feed on leaves and fruits
Assasin bug	*Leptoglosus australis*	Heteroptera	Feed on young stem, flowers, fruits
-	*Campanotus spp.*	Hymenoptera	
Cotton stainer	*Dysdercus superstitiosus*	Heteroptera	Feed on leaves
African mole cricket	*Grallotalpa africana (L.)*	Orthoptera	Feed on leaves
Shorthorn grasshopper	*Melanoplus bivittatus*	Orthoptera	Feed on leaves
Aphids	*Aphis gossypii*(Glover)	Homoptera	Feed on leaves and stems
Psyllid	*Trioza erytrea*	Hymenoptera	Feed on fruits
Melon worm moth	*Diaphania hyalinata*	Lepidoptera	Feed on fruits
Variegated grasshopper	*Zonocerus variegates (L.)*	Orthoptera	Feed on leaves
Melon fruit fly	*Dacus cucurnitae*	Diptera	Feed on fruits
Grasshopper (green)	*Conocephalus longipennis*	Orthoptera	Feed on leaves
Beneficial Insects			
Social wasp	Unidentified	Hymenoptera	Feed on aphids
Ladybird beetle	*Rodolia cardinalis*	Coleoptera	Feed on aphids
Techinid fly	*Winthemia quadripustulata*	Diptera	Feed on caterpillars
Honey bees	*Apis spp.*	Diptera	Pollinate flowers

Table 6. Abundance of major leaf feeders and fruit borers found on cucumber plants treated with different insecticides at the University Farm, Legon, Ghana (Leaf feeders)

Treatments	Epilachna beetle	Cucumber beetle	Aphids	Cucurbit leaf beetle
Control	36	55	203.3	15.5
Calneem	5	5	45	2
NSE	6.5	7	49.5	2.5
Callidim	2.2	2	35	0.5
LSD (P<0.05)	6.5	10.8	50.5	2.5

Table 7. Abundance of major leaf feeders and fruit borers found on cucumber plants treated with different insecticides at the University Farm, Legon, Ghana (Fruit borers)

Treatments	Melon fly	Psyllid	Melon worm moth	Assasin bug
Control	85.4	15.2	10.4	8.5
Calneem	12	2.5	1	1
NSE	15	4	1.5	1.5
Callidim	5.5	1	0.5	0.5
LSD (P>0.05)	10.2	6.2	5.4	3.5

Table 8. Leaf and fruit damage caused by insect pests to cucumber treated with different insecticides at the University Farm, Legon, Ghana

Treatments	Percent leaf damage	Percent fruit damage
Control	16.9	53.5
Calneem	2.1	4.4
NSE	2.7	5.2
Callidim	1.8	4.5
LSD (P<0.05)	5.2	12.5

Table 9. Fruit yield of cucumber treated with different insecticides at the University Farm, Legon, Ghana

Treatments	Mean no of fruits\plants	mean fruit wt. (g)	mean fruit length (cm)	Mean fruit width (cm)	Yield (kg\ha)
Control	1.87	156.1	13.30	3.87	8,203
Calneem	3.70	215.1	16.15	4.35	16,325
NSE	3.40	212.5	16.20	4.28	16,210
Callidim	3.80	215.5	16.23	4.30	16,361

3. Discussion

Several insect species were found associated with the different developmental stages of okra and cucumber plants at the Ashiaman Irrigation Site and the University Farm Legon. Calneem oil, Neem seed extract and Callidim caused significant reduction in the population of some of the major pests of okra and cucumber compared with the control.

The results of this work have confirmed the protectant potential of neem products against several insect species that attack crops (Schmutterer, 1985, 1990; Rodgers, 1993; Youdeowei, 2000; Akakpo et al., 2001; Obeng-Ofori and Kelly, 2001; Obeng-Ofori and Ankrah, 2002; Obeng-Ofori and Sackey, 2003; Adjei-Nsiah et al., 2003; Owusu-Ansah et al., 2003; Obeng-Ofori et al., 2007). Calneem oil, neem seed extract and Callidim 400 EC were equally effective and protected the vegetable plants against infestation by pests with corresponding increase in fruit yield. Neem trees are available throughout the country and the extracts are easy to prepare. Resource-poor vegetable farmers should be encouraged to use this locally available insecticide to protect their crops against pests attack. Calneem oil is also produced and marketed locally in Ghana. Medium to large-scale farmers should also be encouraged to use this commercially available botanical as an alternative or supplement to synthetic insecticides.

Biopesticides such as calneem oil and neem extracts are broad-spectrum in activity, degrade rapidly to harmless metabolites and therefore leave no residues in the environment where they are applied (Schmutterer, 1990). They are also composed of several biologically active ingredients with different modes of action. The probability of insects developing resistance to such products is therefore low compared to synthetic pesticides. The use of calneem oil and neem seed extracts can form an important component of pest management strategies, especially in the developing countries with critical foreign exchange problems (Obeng-Ofori and Akuamoah, 1998).

Field trails in the use of Calneem oil and extracts of neem seeds and leaves for the management of insect pests of vegetables, food and fruit crops continue to be conducted by IPM trainers and farmers in various parts of Ghana. Farmers are rapidly adopting the use of neem products in a variety of crop production systems including irrigated rice, cowpea, pepper, cabbage, okra, eggplant and onions (Youdeowei, 2000).

There is no doubt that the successful utilization of botanicals such as neem products can help to control many of the world's destructive pests and diseases, as well as reduce erosion, desertification, deforestation, and perhaps even control human population due to the anti-fertility action of some of them such as the neem. Although the possibilities of using botanical pesticides seem almost endless, so many details remain to be clarified. Many obstacles must be overcome and many uncertainties clarified before their potential can be fully realised. These limitations seem surmountable; however, they present exciting challenges to the scientific and economic development communities. Solving the following obstacles and uncertainties may well bring a major new resource which will benefit much of the world. These obstacles include doubts to their efficacy due to their slow action and lack of rapid knock-down; lack of standardization of botanical pesticide products; changes in their potency with location and time with respect to geographical limitations; instability of the active ingredients when exposed to direct sunlight; and high cost of commercially formulated botanical pesticides.

Clearly, the potential for the use of biopeticides especially neem products in crop production is extremely high and farmers need to be educated on the economic and environmental benefits of neem products. Furthermore, refining aqueous neem extracts to standardize the most effective dosage for different pests and crop production systems as well as accurate economic evaluation of the sustainability of their usage for the management of crop pests need urgent attention (Youdeowei, 2000). Governments and development agencies in the developing world should therefore encourage and promote the preparation and adoption of neem products at both factory and farm level by resource-poor and medium to large-scale farmers, respectively to protect their crops against insect pest infestation.

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