Comparative efficacies of three insecticidal materials and steam treatment for protection of Bambara groundnut against *Callosobruchus maculatus* (Fab.) (Coleoptera: Bruchidae)

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ABSTRACT

The efficacy of four protectants, actellic, neem seed oil, neem kernel oil, and hydrothermal treatment (steam), for protection of two varieties of Bambara groundnuts, namely Jabajaba and Piele Balgu, against *Callosobruchus maculatus* were assessed using grain damage, progeny production, and seed viability assays. Bambara groundnut seeds treated with actellic, steam or neem seed oil significantly reduced seed damage and the number of F1 progeny produced by *C. maculatus* compared to the untreated seeds. All the dry seeds treated with steam did not germinate when kept in moist filter paper in Petri dishes for 5 days, indicating that steam should not be applied to seeds destined for propagation. Resource-poor farmers can use neem seed oil or steam treatment to protect Bambara groundnut against infestation by *C. maculatus* in storage.

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RÉSUMÉ

OBENG-OFORI, D. & DANKWAH, J. A.: *Efficacités comparées de trois matières insecticides et le traitement à vapeurs pour la protection du voandzou contre* Callosobruchus maculatus *(Fab.) (Coleoptera: Bruchidae).* L'efficacité de quatre phytoprotecteurs actéllique, huile de graine de margousier, huile d'amande de margousier et le traitement hydrothermique (vapeur), pour la protection de deux variétés de voandzou à savoir, Jabajaba et Piele Balgu contre *C. maculatus* étaient évaluées en utilisant dommage de graine, production de progéniture et les essais de la viabilité de graine. Les graines de voandzou traitées avec actéllique, vapeur ou l'huile de graine de margousier, reduisaient considérablement le dommage de graine et le nombre de progéniture F1 produite par *C. maculatus* en comparaison de graines non-traitées. Tous les graines sèches traitées avec la vapeur ne germaient pas lorsqu'elle étaient mises sur le papier filtre dans les boîtes de Petri pour cinq jours, indiquant que la vapeur ne doit pas être appliqué aux graines destinées à la propagation. Les pauvres cultivateurs pleine de resource pourront utiliser huile de graine de margousier ou le traitement à vapeur pour protéger le voandzou contre infestation par *C. maculatus* en stockage.

Introduction

Bambara groundnut, *Vigna subterranea* (L.) Verdc. is cultivated throughout Africa but remains a neglected crop because it has not been studied extensively. However, empirical evidence and fragmentary research results suggest that it is a crop with much promise. It is drought-tolerant, thrives on poor soils, and is generally free of diseases during growth (Sellschop, 1962). It is one of the major grain legumes consumed in Africa; ranking third to cowpea and groundnut (Sellschop, 1962). Bambara groundnuts are cheap sources of carbohydrates and proteins in the diets of humans and livestock in Africa. The seeds are highly nutritious and contain more lysine and methionine than either cowpea or groundnut

(Ezedinma & Maneke, 1985). Bambara groundnut is a complete food and is eaten as either immature or fully ripe. The fresh semi-ripe seeds are eaten fresh or boiled, while the dry seeds are often pounded into flour and mixed with oil or butter to form porridge or sometimes roasted in oil. The young whole pods are used in soups.

The shelled nuts are very susceptible to insect infestation which may start from the field. However, serious insect damage occurs during storage (Warui, 1984; FAO, 1985). The cowpea beetles, *Callosobruchus maculatus* (Fab.) and *C. subinnotatus* (Pic.), are the major storage pests of Bambara groundnut (Cornes, 1971; Mbata, 1987). *Callosobruchus maculatus* originated in Africa where it is still the dominant species of *Callosobruchus* found. Infestation of Bambara groundnut by *C. maculatus* causes qualitative and quantitative losses (Haines, 1991). Consumption of part of the cotyledon reduces the weight of the seed and the embryo may also be damaged. Infested seed is contaminated with frass and assumes an unpleasant odour (Allotey & Oyewo, 1993).

The nutrient content and diverse dietary usage of Bambara groundnut suggest that it could be an inexpensive substitute for animal protein to rural and urban poor Ghanaians. Promotion of its cultivation in Ghana would be enhanced if an effective method to control the major storage pests is developed. This will help increase the farmers' income and ensure food security among resource-poor growers in Ghana.

Dankwah (1998) found that farmers stored their produce in locally constructed silos for up to 9 months and applied actellic 25EC to protect stored Bambara groundnut against insect pest infestation. The dependence on synthetic insecticides for controlling stored product pests has given rise to several problems such as the development of resistant strains of insects, toxic residues in the grains, and some health hazards to applicators and consumers (Youdeowei, 2000). Furthermore, with the removal of subsidies on all agricultural inputs in Ghana, pesticides have become too expensive to most small-scale farmers. Some farmers, therefore, apply insecticides recommended for cotton and cocoa to protect their grains (Youdeowei, 2000). Alternatives to the use of pesticides need to be urgently identified and introduced to the farmers. One such alternative is the use of botanicals.

The protection of stored products with botanicals is a common practice among small-scale farmers in Africa (Golob & Webley, 1980; Delobel & Malonga, 1987; Don-Pedro, 1989; Hassanali *et al.,* 1990; Obeng-Ofori, 1995; Obeng-Ofori *et al.,* 1997, 1998, 2002; Bouda *et al.,* 2001). Plant-derived pesticides are active against many storage pests as antifeedants, repellents or toxicants, and are less hazardous (Prakash *et al.,* 1982; Obeng-Ofori & Akuamoah, 2000, 2001; Obeng-Ofori & Freeman, 2001; Obeng-Ofori & Amiteye, 2000). The seeds of neem tree, *Azadirachta indica* A Juss (Melliacae), are rich in insect-deterrent and insecticidal terpenoids which act as repellents, antifeedants, and growth inhibitors (Schmutterer, 1985, 1990). Neem is, therefore, a promising alternative to synthetic insecticides and is the most widely investigated and effective plant material used to control insect pest of stored products (Schmutterer, 1985; Tanzubil, 1986; Cobbinah & Appiah-Kwarteng, 1989; Allotey & Dankwah, 1994).

The exposure of legume seeds to steam is a physical method which affects the oviposition and development of *C. maculatus,* since it is selective in its site for oviposition. Several factors either stimulate or inhibit oviposition of the beetle. Among them are the texture of the seed coat (Nwanze *et al.,* 1975), surface odours of the seed which may either attract or repel the insect (Nwanze & Horber, 1976; Giga & Smith, 1985), and the shape or curvature of the seeds (Horber, 1978). Nwanze & Horber (1976) reported that differences in the seed coat of cowpea affect oviposition and larval development of *C. maculatus,* as the insect prefers sound and healthy seeds to wrinkled and infested seeds (Pathak, 1986).

This paper reports on the laboratory evaluation of the protectant potential of neem products and physical exposure of seeds to steam for protection of stored Bambara groundnut against damage by *C. maculatus*.

Materials and methods

Market survey

A market survey was conducted in five local markets in and around Accra to assess the infestation of Bambara groundnut by *Callosobruchus,* and to determine the major pests of the legume. The markets visited were Malata, Makola, Madina, Kasoa, and Agbogbloshie. One-kilogramme samples of insect-infested Bambara groundnut were purchased from five randomly selected spots in each of the five markets. In the laboratory, all foreign matter was removed from the seeds by sorting and sieving. The samples from each market were kept in different rearing jars till the emergence of adult insects. The adult insects that emerged from these samples were removed daily with a mouth aspirator and identified to species, using the serrated antennae and the two dark patches situated halfway along each elytron (Mbata, 1987, 1992).

Varieties of Bambara groundnut used

Two local varieties of Bambara groundnuts, namely Jabajaba and Piele Balgu, were purchased from the Accra Newtown Market and stored in a Freezer till they were needed. Jabajaba is the dominant variety grown in the Dangme East District of Ghana. The Piele Balgu variety is one of the common varieties grown in northern Ghana (Allotey & Dankwah, 1994).

Rearing of insects

Adults of *C. maculatus* were reared on Bambara groundnut which had been sterilized at 60 °C in a Gallenkamp oven for 1 h (Murdock & Shade, 1991). The parent stock of insects were collected from infested cowpea bought from the Madina market in Accra. One hundred randomly selected unsexed adult *C. maculatus* were introduced into 600 g of sterilized Bambara groundnut in 1 litre rearing jars (12 cm × 12 cm) and kept in the Physiology Laboratory of the Zoology Department of the University of Ghana, Legon. The laboratory was maintained at 28 ± 2 °C and 60 - 65 % RH. The seeds were sieved to remove all dead insects after 14 days. Progeny emergence started after 21 days, and the emerging F1 adults were immediately used for the various assays. The glass jars were arranged in trays mounted over oil to prevent cross infestation (Allotey & Goswani, 1991).

Preparation of plant materials

Ripe neem fruits were harvested from trees on the campus of the University of Ghana, Legon. The fruits were kept in the dark in the laboratory for 2 days to soften the mesocarp which were then removed. The seeds were dried in the shade for 5 days. The endocarp of the seeds were cracked to remove the kernels, which were milled with an electric mill to particle size of 5 μm (Allotey & Oyewo, 1993). An extract of the milled kernel was prepared with ethanol in the Soxhlet rotor-evaporated distillation apparatus (Sanaa, 1988) at the Physiology and Biochemistry Laboratory of the Cocoa Research Institute of Ghana, Tafo. Five grammes of the neem kernel cake were washed with 100 ml of ethanol in the Soxhlet apparatus for 5 h. The extract was concentrated using the Kjedhal apparatus at 100 °C. The oily extract was preserved in tightly corked glass vials and stored in a refrigerator till they were needed (Islam, 1983).

Actellic 25EC

Actellic is an organophosphorous insecticide containing the active ingredient pirimiphosmethyl for the control of field and storage insects. In storage facilities, actellic controls flying and crawling insects including beetles, weevils, mite and borers of cereals and legumes. It was applied by mixing Bambara groundnut with 4 ml of actellic in a litre of water. One thousand seeds of each variety of Bambara groundnut were treated with actellic at 4 ml/l and allowed to air dry for 24 h.

Application of neem seed oil and neem kernel oil

Ten millimetres each of the neem seed oil or neem kernel oil were first emulsified using 2 ml of teepol and then diluted to 1000 ml to form a 1% solution. The solutions were used to treat 1000 seeds of each variety of Bambara groundnut using a hand sprayer. The treated seeds were air-dried for 24 h.

Steam treatment

Steam, generated from boiling water in a 200 cm × 50 cm bowl, was passed over batches of Bambara groundnut seeds in a 200 mm × 50 mm, Mw 2.5 mm sieve for 15 min. Each batch had 1000 seeds spread thinly over the undersurface of the sieve. The seeds were oven-dried at 40 °C for 30 min in a Gallenkamp oven. The control seeds were not exposed to steam.

Assessment of damage caused by C. maculatus

A pair of *C. maculatus* was introduced onto the seeds contained in glass jars (5 cm × 12 cm). Each jar contained 1000 seeds and was covered with nylon mesh held in place with rubber bands. Ten replicates for each treatment were set up in wooden trays. Jars containing different treatments were kept in separate trays. The progeny started emerging from the 22nd day after the experimental set-up. The experimental design was a randomised complete block design. *Callosobruchus maculatus* laid their eggs on the seed coats. These eggs hatched and the larvae penetrated and developed in the seeds. The developing larvae fed on the cotyledon and embryo of the seeds. Their feeding created windows in the seed coat. The young adults emerged out of the seeds through these windows. Damage was assessed as numbers of emergent holes by counting the number of emergent holes and estimating weight loss by the FAO (1985) method, using the following equation:

$$\% \text{ wt loss} = \frac{[\,UaN - (U + D)]}{UaN} \times 100$$

or

$$100 \times \frac{(\text{Initial seed wt - Final seed wt})}{\text{Initial seed wt}}$$

where U = weight of undamaged fraction in the sample
Ua = average weight of undamaged grain
D = weight of damaged fraction in the sample
N = total weight of seeds

Progeny emergence

Different lots of Bambara groundnut seeds were treated with 1 per cent neem seed oil, 1 per cent neem kernel oil or actellic at 4 ml/l. Another lot of seeds were also exposed to steam for 15 min and oven-dried at 40 °C for 30 min. The seeds for the control experiment were not treated with any material. A pair of 1-day-old *C. maculatus* adults was introduced into 5 cm × 12 cm glass jars containing 1000 seeds of Bambara groundnut. Each treatment was replicated 10 times in separate jars. The pair of beetles introduced was removed 14 days after introduction. The adults which emerged each day were also removed from the jars with a mouth aspirator and kept in Petri dishes. The beetles in the Petri dishes were examined daily to record their longevity.

Viability test

Bambara groundnut seeds were treated, and a viability test was carried out on the seeds by separately placing 10 seeds of each variety in plastic Petri dishes in the laboratory. Each Petri dish was lined with two pieces of Whatman No. 1 filter paper and kept moistened throughout the experiment. The seeds were arranged with their hilum touching the moist filter paper to facilitate absorption of water. Each treatment was replicated 10 times. Seeds were considered to have germinated when the radicle emerged from the seed coat. The number of seeds that germinated from the different treatments after 5 days was recorded and percentage germination was calculated.

Analysis of data

The data collected were transformed to $\log_{10}(n+1)$ and analyzed using ANOVA. Differences between means were measured at the 5 per cent level of significance. The data on seed viability were transformed into arcsine before the ANOVA was performed. The LSD at 5 per cent was used to separate the means.

Results

Market survey

From the seeds collected in the five local markets in and around Accra, namely Malata, Makola, Madina, Kasoa and Agbogbloshie, two species of *Callosobruchus, C. maculatus* and *C. subinnotatus,* were found infesting Bambara groundnut during storage (Table 1). *Callosobruchus maculatus* was the predominant species and constituted 70 per cent of the beetles that emerged.

TABLE 1

Mean Number of Adult Callosobruchus *Reared from Bambara Groundnut Collected from Five Markets in and Around Accra in November 1999*

Market	*Mean number of* Callosobruchus *adults found in grain sample*		
	C. maculatus	C. subinnotatus	*Total*
Malata	76	11	87
Makola	52	0	52
Madina	30	29	59
Kasoa	56	0	56
Agbògbloshie	22	60	82
Total	236	100	336
Percentage	70.24	29.76	100

Progeny emergence and damage assessment

Tables 2 and 3 show the effect of the different treatments on adult emergence and damage caused by *C. maculatus*. The number of adults that emerged from the untreated Piele Balgu and Jabajaba were 65.4 and 40.6, respectively (Table 2). The trend of adult emergence, seed damage, and weight loss was similar for both varieties (Table 3). Analysis of variance showed that prog-

TABLE 2

Efficacy of Four Protectants for Protecting Two Bambara Groundnut Varieties from Damage Caused by C. maculatus *(X ± SE)*

Treatment	*No. of adults that emerged*	*No. of seeds damaged*	*% weight loss*
Piele Balgu Bambara groundnut			
Control	65.4 ± 8.7	42.4 ± 3.7	25.2 ± 2.4
Actellic	1.1 ± 0.2	1.0 ± 0.1	0.8 ± 0.2
Steam	9.9 ± 2.2	9.5 ± 2.1	10.1 ± 1.9
Neem seed oil	18.2 ± 2.6	12.8 ± 2.0	11.5 ± 1.5
Neem kernel oil	45.0 ± 6.3	36.4 ± 2.7	20.7 ± 2.5
LSD (5 %)	8.6	8.4	5.1
Jabajaba Bambara groundnut			
Control	40.6 ± 3.7	30.4 ± 2.5	22.3 ± 4.5
Actellic	1.1 ± 0.2	1.0 ± 0.1	0.6 ± 0.2
Steam	9.5 ± 2.5	8.9 ± 2.0	6.9 ± 1.7
Neem seed oil	17.9 ± 2.6	13.4 ± 2.2	10.4 ± 1.7
Neem kernel oil	25.5 ± 3.4	21.4 ± 2.6	15.0 ± 2.0
LSD (5 %)	8.2	7.5	5.1

TABLE 3

Developmental Period (Days) and Progeny Emergence of C. maculatus *in Jabajaba and Piele Balgu Varieties of Bambara Groundnut Treated with Four Protectants*

Treatment	*Adult emergence (no. of adults)*	*Developmental period (days)*	*Longevity (days)*
JabajabaBambara groundnut			
Control	40.3 ± 4.1	21.0 ± 0.3	13.9 ± 2.1
Actellic	0.9 ± 0.3	21.5 ± 3.0	9.2 ± 0.6
Steam	18.9 ± 1.6	22.2 ± 0.7	9.5 ± 1.4
Neem seed oil	19.2 ± 1.5	21.1 ± 0.5	13.6 ± 1.5
Neem kernel oil	31.3 ± 3.4	21.0 ± 0.8	12.4 ± 0.9
LSD (5 %)	9.0	4.0	4.5
Piele Balgu Bambara groundnut			
Control	50.6 ± 3.2	21.2 ± 0.5	13.9 ± 0.9
Actellic	0.9 ± 0.3	22.6 ± 0.7	8.3 ± 0.8
Steam	23.9 ± 1.6	22.8 ± 0.5	10.0 ± 0.7
Neem seed oil	18.3 ± 1.6	22.5 ± 0.8	13.9 ± 1.2
Neem kernel oil	45.5 ± 2.4	21.4 ± 0.6	13.4 ± 1.4
LSD (5 %)	9.8	3.3	4.5

eny production was significantly reduced when seeds were treated with actellic, steam, or neem seed oil (Table 2). Consequently, a reduction in adult emergence reduced damage caused by the beetle to the seeds. Actellic-treated seeds recorded the lowest adult emergence and seed damage. Neem seed oil and steam treatment of seeds also caused significant (P<0.05) reduction in adult emergence and seed damage (Table 3). Actellic and neem seed oil provided the greatest protection of the seeds against infestation by *C. maculatus.*

Developmental period and longevity of C. maculatus *bred on Bambara groundnut*

Table 3 shows the effect of the four protectants on the longevity and progeny production of *C. maculatus*. Analysis of variance showed significant reduction (P<0.05) in progeny production from the seeds treated with actellic, steam, and neem seed oil. Longevity of adult *C. maculatus* was 13.9 days on the untreated seeds of both varieties. Actellic and steam caused significant reduction (P<0.05) in longevity of *C. maculatus* compared to the control. None of the protectants caused any changes in the developmental period.

Viability test

Table 4 summaries the percentage germination of seeds over a period of 5 days. Actellic caused significant (P<0.05) reduction in the germination of both varieties of Bambara groundnut compared to the untreated seeds. None of the seeds treated

TABLE 4

Mean Percentage Germination of Bambara Groundnut Exposed to Four Protectants (X ± SE)

Treatment	*Mean % germination (X ± SE)*	
	Jabajaba variety	*Piele Balgu variety*
Control	82.0 ± 0.9	80.0 ± 0.6
Actellic	58.0 ± 0.6	58.0 ± 0.9
Steam	0.0 ± 0.0	0.0 ± 0.0
Neem seed oil	95.0 ± 0.9	100.0 ± 0.0
Neem kernel oil	81.0 ± 1.4	78.0 ± 0.8
LSD (5 %)	10.0	10.0

with steam germinated. However, neem seed oil improved on germination of Bambara groundnut seeds significantly ($P<0.05$).

Discussion

The survey of five major markets in the neighbourhood of Accra indicated that two species of *Callosobruchus,* namely *C. maculatus* and *C. subinnotatus,* infest Bambara groundnut. The development of an individual *C. maculatus* takes place in a single seed. The developmental period of an adult *C. maculatus* differs on different legumes (Southgate *et al.,* 1957). A long developmental period on a particular legume variety indicates that the food medium is unsuitable for larval development or that the insect is unable to use the food material efficiently (Allotey & Oyewo, 1993). In the study reported here, the developmental period was not significantly different ($P>0.05$) for the treated and untreated seeds.

Bruchids show a pattern of daily emergence on different varieties of legume (Allotey & Dankwah, 1994). The number of *C. maculatus* increases gradually from the 1st day of emergence to a peak and then declines until emergence of the beetle stops. A peak of emergence of *C. maculatus* recorded earlier on a legume variety indicates that the variety is more susceptible to infestation. The number of *C. maculatus* that emerged was significantly lower on treated seeds (Tables 2 and 3). All the treatments significantly ($P<0.05$) reduced the emergence of *C. maculatus* on the Jabajaba and Piele Balgu varieties compared to the untreated seeds. Actellic was the most effective product against *C. maculatus.* Actellic is an insecticide that has a rapid knockdown effect on contact. It also interrupts the development of eggs into adults.

Steam treatment of cowpea seeds makes the testa rough. This had been shown to be an effective method of controlling *Callosobruchus* infestation (Cockfield, 1992) by reducing the availability of oviposition sites, since the beetle prefers laying eggs on seeds with smooth testa (Nwanze *et al.,* 1975). This method is fairly cheap, has no mammalian toxicity, and poses no environmental problems. It also does not require any special training or equipment. However, steaming of Bambara groundnut seeds does not offer permanent protection to treated seeds (Cockfield, 1992) and cannot be used on seeds destined for propagation, since it reduces seed viability as reported in this study.

The neem seed oil is regarded as an ovicide and also served as an antifeedant and suppressed the feeding of *C. maculatus* larvae. Neem kernel oil also reduced the emergence of *C. maculatus,* but to a lesser extent due to its lesser content of the active ingredient, azadirachtin, compared to the neem seed oil (Schmutterer, 1990). Many workers have demonstrated the efficacy of neem oil for the control of major storage pests (Yadav, 1985; Tanzubil, 1986; Schmutterer, 1990; Cockfield, 1992; Allotey & Oyewo, 1993). Tanzubil (1986) reported that treatment of cowpea seeds with neem oil at the rate of 5 ml kg^{-1} protected the grains against infestation by *C. maculatus* for several months in West Africa. The oil blocks the tunnels attached to the eggs of *Callosobruchus;* thus, preventing their development into larvae (Yadav, 1985).

The damage caused by *C. maculatus* was indicated by the emergent holes on the host seeds. When the damage was assessed, the results showed that damage caused to untreated seeds was significantly ($P<0.05$) higher than that in treated seeds for the Jabajaba and Piele Balgu varieties. All the products evaluated reduced the feeding activity of *C. maculatus* compared to the control. Thus, actellic, neem seed oil, and steam provided adequate protection for both varieties of Bambara groundnuts against infestation by *C. maculatus.*

The longevity of *C. maculatus* that emerges from seeds of legumes depends on the amount of food reserve in the insect. Edezinma & Maneke (1985) reported that higher adult longevity is associated with better or more nutritious larval food medium. Adult longevity of *C. maculatus* was 13.9 days for the untreated seeds of both Bambara groundnut varieties (Table 3). The longevity of *C. maculatus* reared on actellic and steam-treated seeds was significantly ($P<0.05$) reduced. The pirimiphos-methyl in the actellic hastens the development of *C. maculatus* (Anon., 1991) to yield adults which die earlier than normal. Steam treatment causes hydrolysis of vital seed components, notably carbohydrates that are essential for the growth and development of adults of *C. maculatus* (Gatehouse *et al.,* 1979). This might have adversely affected the various developmental stages of the beetle.

Seed germination of the untreated Bambara groundnut seeds of both varieties after 5 days was over 95 per cent. No seed exposed to steam germinated. Actellic also retarded germination of seeds of the two varieties of Bambara groundnuts, but neem oil improved seed germination. Azadirachtin in neem has been found to promote vegetative growth, enhance seed germination, and protect germinating seeds from pathogens that disturb the process (Lehmann *et al.,* 1993). The germination-enhancing activities of neem and its ability to act as a fungicide could account for the improvement of germinability of seeds treated with it.

A discussion of the efficacy and residual effects of alternatives to the use of synthetic chemicals should include an assessment of the social impact of these methods to enable the ordinary farmer to appreciate and select the best alternative to the use of synthetic chemicals. Steam treatment of Bambara groundnut involves generating steam from water. The essential resources in the process, namely fuel, wood and water, are readily available in most farming communities. However, the burning of wood for heating contributes towards the depletion of the forest wood supply, and is also a source of polluting the atmosphere with smoke. Steam treatment is useful in reducing damage of Bambara groundnut by *C. maculatus* infestation. The viability of the seeds is, however, lost through the process. The method can, therefore, not be used on seeds destined for propagation. It may also be laborious to treat large quantities of grains with steam, unless appropriate equipment is developed to facilitate the steaming process.

Neem oil is extracted from neem seeds and can be stored in a refrigerator till it is needed for use. The process of preparing neem seed oil is diverse, depending on the facilities available. Neem seed oil is potent in reducing damage to Bambara groundnut by *C. maculatus.* The oil also promotes germination of seeds and vegetative growth. However, the bitter taste imparted to some crops by neem products needs to be corrected by washing them with water before they are used. Steam treatment is, therefore, appropriate for storage of seeds to be consumed while neem treatment can be applied to seeds destined for consumption or propagation. The authors have initiated a comprehensive community-based field evaluation of the use of neem seed oil and hydrothermal treatment as a component of integrated management of farm-stored grains by resource-poor farmers in Ghana to minimize the use of synthetic pesticides and their attendant hazards.

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