Efficacy of extracts from *Hyptis spicigera* Lam. against *Callosobruchus maculatus* F. (Coleoptera: Bruchidae) in Kersting's groundnut (*Macrotyloma geocarpum* Harms)

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ABSTRACT

Aqueous foliage extracts from *Hyptis spicigera* Lam. at 10 and 20 per cent concentrations were applied at 25, 50 and 100 °C on the seeds of Kersting's groundnut (*Macrotyloma geocarpum* Harms), to evaluate their bioefficacy against the pulse beetle, *Callosobruchus maculatus* F. and the effects on viability of the seeds. The experiment was laid out in a completely randomized design with four replications. Data were collected on the infestation and damage caused by the pest, and on the viability of treated seeds. The results showed that the oviposition, progeny emergence, developmental period, adult longevity of the pest, and damage on the seeds were significantly affected by the extract applied. All the extract treatments were found to offer better protection than the untreated seeds in most of the parameters evaluated. Insecticidal efficacy was found to show a dose- and temperature-dependent response. Extracts at 20 per cent concentration, treated at 50 °C or 100 °C, offered protection comparable to that of the synthetic insecticide, Pirimiphos-methyl at 20 g kg^{-1}. Extracts treated at 100 °C, however, showed significant reduction in the germination percentage of the seeds. The implications of these findings are discussed with the view to developing more sustainable means of protecting Kersting's groundnut grains from bruchid attack so as to minimise the rampant postharvest losses to the crop in the savanna ecology of Ghana.

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Introduction

Kersting's groundnut, *Macrotyloma geocarpum* Harms, is an important grain legume cultivated in parts of West Africa (Okigbo, 1992; Duk, Okigbo & Reed, 1977). In Ghana, the crop is mainly produced along the Guinea savanna belt, particularly in the Northern, Upper East and Upper West regions (Bayorbor, Badii & Avornyo, 2002). In most communities, the mature bean-like seeds are well known for their nutritional and medicinal significance (Obasi & Agbaste, 1994). However, as in the case of other legumes such as cowpea and Bambara groundnut, harvested Kersting's groundnut grains are very susceptible to infestation by the storage bruchid, *Callosobruchus maculatus* F., which is capable of rendering the unprotected seeds unviable and unsuitable for utilisation as food within few months of storage (Amponsah, 2007). The control of the pest is crucial for the sustainable production, safe preservation and utilisation of this neglected and underutilised, but economically

important crop among rural and urban households in West Africa.

The use of commercial synthetic insecticides in the control of *C. maculatus* has been unsustainable owing to their high cost, unavailability in local markets and associated health and environmental risks (Wolfson *et al.*, 1991; Jakai & Adallah, 1997). To reduce the over dependence on the use of chemical insecticides to control bruchid pests in Kersting's groundnut, there has been the need to explore the insecticidal potentials of locally available plant-derived products which are quite effective, biodegradable, safe, and more affordable to the local farmer (Rahaman & Talukder, 2006). The use of locally available plant products to minimise insect damage is a widespread practice in traditional farm storage in West Africa. Many workers have reported the effectiveness of different plant materials against major storage insect pests in Ghana (Obeng-Ofori & Freeman, 2001; Osekre & Ayertey, 2002; Boateng, Obeng-Ofori & Biney, 2006). Plant species used by different communities vary from place to place, and appear to depend on the type and efficacy of suitable materials available in the locality (Hassanali *et al.*, 1990; Niber, 1994; Talukder & Howse, 1994; Obeng-Ofori & Freeman, 2001).

Hyptis spicigera Lam. is an annual herbaceous weed which is widespread in northern Ghana. It contains triterpenoid with low mammalian toxicity, which has been used in the control of stored grain pests (Sanon *et al.*, 2006; Othira *et al.*, 2009), the treatment of various ailments, and as insect repellent (Abbiw, 1990). A comprehensive re-evaluation of different plant materials that are used in different communities in Ghana by local farmers to protect stored grains against insect pests has been initiated to understand their biological activities and protectant potentials. This would help develop more appropriate formulation, and effective application methods that are adaptable to local conditions of subsistence farmers who cannot afford synthetic insecticides. This evaluated the biological effects of aqueous extracts from the foliage of *H. spicigera* Lam. on the infestation and damage by *C. maculatus* F. in stored seeds of Kersting's groundnut. The oviposition deterrence, developmental inhibition and residual toxicity of the extracts on the insect, and their effects on the viability of the seeds were assessed in the laboratory.

Materials and methods

Source of Kersting's groundnut seeds

The white-seeded landrace cultivar of Kersting's groundnut grains were used for the study in the Biology Laboratory of the University for Development Studies (UDS) in Nyankpala, between January and July 2010. The seeds were obtained from farmers' fields around Funsi in the Wa East District of the Upper West Region of Ghana, during the 2009 harvesting season. Before the experiment, the seeds were stored in the cold room at 10 °C and 70-100 per cent relative humidity (RH) to ensure that they were free from attack by postharvest insects or pathogens.

Preparation of extracts and seed treatment

The fresh foliage (leaves and flower heads) of *H. spicigera* Lam. were harvested around the UDS-Nyankpala Campus and neighbouring communities in September 2009. These were washed and air dried in a well-ventilated screen house for 2–5 days to constant weight. The dried material were ground to powder using an electronic grinder, and the powder passed through a 25-mesh sieve to obtain the fine dust, which was used to prepare the extracts at 10 and 20 per cent concentrations.

The method of preparation of extracts was chosen on the basis of simplicity, ease of adoption and convenience of use by the local farmers. It has been established that in the preparation of aqueous neem extracts, about 20 per cent (by weight) of the powdered material go into the aqueous phase, hence, to obtain a 5 per cent solution of the extract, about 600 g of the material would be added to 15 *l* of water (Dreyer, 1984). Thus, the 10 per cent aqueous extract (AE) was

prepared by soaking 600 g of the fine dust in 7.5 *l* of water, and the content was stirred and kept for 48 h before it was filtered through Whatman No.1 filter paper. The same principle was followed to obtain the 20 per cent aqueous solution using 1200 g fine dust to 7.5 *l* of water.

Each extract concentration was kept in a glass bottle and stored in a refrigerator until needed. At the time of application, each solution was divided into three equal parts for adjustment into three different temperatures; i.e. 25, 50 and 100 °C. To achieve this, each extract was put in a beaker and heated on a burner with a thermometer inserted into it for reading the desired temperature. The resulting solutions were used to treat the Kersting's groundnut seeds by soaking 200 g of seeds in 200 ml of each extract. Each mixture was allowed 15 min for the active ingredients to penetrate the seed coats, after which the solutions were drained out and the seeds air-dried in ventilated screen house to 12 per cent moisture content. The treated seeds were used for the various experiments, which were maintained at 25 ± 2 °C, LD 12:12 and 70 ± 5 per cent R. H. in the laboratory. Actellic dust (Pirimiphos-methyl 50 EC at 20 g kg^{-1}) was used as a standard insecticide check together with the untreated control, according to the method described by Boateng *et al.* (2006). The experiment was laid out in a complete randomized design (CRD) with four replications.

Rearing of experimental insects

Adult *C. maculatus* used in the study were originally obtained from infested samples of Kersting's groundnut seeds in a laboratory stock. They were reared and bred under diet of Kersting's groundnut seeds inside a growth chamber at 27 ± 2 °C with L D 12:12 and 70 ± 5 per cent R. H. Initially, 50 pairs of newly emerged (1-24 h old) adults were placed in jars containing the seeds. The jars were covered with fine nylon mesh at the open ends, and a maximum of 2 days were allowed for mating and oviposition. The parent stocks were removed and the seeds containing eggs were transferred to fresh seeds in the rearing jars which were covered with pieces of cloth, fastened with rubber bands, to prevent the contamination of the seeds and escape of the insects. The subsequent F_1 progenies of the beetles were used for the experiments.

Oviposition and progeny emergence

Laboratory test for oviposition inhibition was conducted according to the method of Osekre & Ayertey (2002) with some modifications. Fifty Kersting's groundnut seeds from each treatment were put in 250-ml kilner jars. Each seed sample was infested with five pairs of newly emerged (1-24 h old) *C. maculatus,* and allowed a maximum of 7 days to mate and lay eggs. After this period, a sample of 20 seeds from each treatment was picked and examined individually to record the number of egg cases. The set up from the oviposition experiment was kept for 25 days during which the F_1 progenies continued to emerge. On the 30th day, the number of adults that emerged, either alive or dead on the treated seeds in each jar, was counted. The percentage adult emergence was calculated as the proportion of adults that emerged from the number of eggs laid on the seeds in each sample.

Developmental period and adult longevity

To determine the development period, samples of 50 seeds from each treatment, kept in petri dishes, were infested with five pairs of the newly emerged beetles and allowed 2 days to mate and lay eggs, after which they were removed from the seeds. The set up was kept and examined daily to remove and count any emerged beetle from the petri dishes using an aspirator and illuminated magnifier. The experiment was terminated 21 days from the date of first adult emergence. The mean development period was determined as the average time (in days) taken for the beetles to develop from egg to adult on each seed sample.

Live beetles that were removed daily from the petri dishes of each treatment were kept in separate petri dishes without seeds and observed for 48 h,

during which those insects that did not move or had uncoordinated movement when probed with a hairbrush were considered dead. This was recorded as the length of time the adult could live after emergence from the treated seeds.

Residual toxicity and seed viability

Test of residual toxicity of the extracts was conducted according to Talukder & Howse (1994) with some modifications. Seed samples (500 g) from each treatment were kept in small separate pots. Ten pairs of the newly emerged adult beetles were introduced at the centre of each pot and enclosed with a cover and allowed 2 days for the insects to oviposit, after which they were removed from the pots using an aspirator and illuminated magnifier. The set up was kept for 40 days for the insects to develop. The following data were collected: Number of exit holes (windows) on 100 seeds, and percentage seed weight loss (PWL) expressed as PWL = [UNd DNu/ U (Nd + Nu)] × 100 (where U = Weight of undamaged grain, D = Weight of damaged grain, Nd = Number of damaged seeds and Nu = Number of undamaged seeds) (Rahaman & Talukder, 2006).

The treated seeds, and the controls were all tested for their viability in the laboratory. Fifty seeds from each treatment were placed separately in glass jars free from insects for 4 months, after which seeds from each treatment were placed on moist filter paper in petri dishes and kept in an incubator at 25 °C, 12 h photoperiod and 70–100 per cent R H. conditions. They were observed for 7 days after which the percentage seed germination was recorded.

Statistical analysis

All data collected were subjected to the analysis of variance (ANOVA) using Genstat edn 3 software. Numerical and percentage data were log and arcsin transformed, respectively, to normalise the error distributions before the analysis. Where ANOVA test indicated significant difference, treatment means were separated by Fishers' least significant difference (LSD) test.

Results

Oviposition and progeny emergence

The effects of the extracts on the ovipotition of adult females of *C. maculatus* on the Kersting's groundnut seeds are presented in Table 1. The results showed that significantly higher number of eggs were laid on seeds treated with 10 per cent AE at 25 °C or 50 °C, while seeds treated with

TABLE 1

The Effects of Aqueous Extracts (AE) from Foliage of H. Spicigera *Lam. at Different Concentrations and Temperatures on the Oviposition of C. maculatus on Kersting's Groundnut Seeds*

Treatment	*No. of eggs laid*	*Per cent oviposition inhibition**
Control	121.0± 4.2 a	–
10% AE at 25 °C	51.3± 2.3 b	57.4± 2.2 a
10% AE at 50 °C	45.5± 2.2 bc	62.8± 2.7 ab
10% AE at 100 °C	32.0± 1.9 c	73.5± 2.8 b
20% AE at 25 °C	35.5± 2.0 c	70.6± 2.5 b
20% AE at 50 °C	20.5± 1.7 cd	83.0± 3.4 bc
20% AE at 100 °C	14.0± 1.3 d	88.4± 3.7 c
Pirimiphos-methyl	19.0± 1.5 d	84.3± 3.5 c
LSD ($P < 0.05$)	12.51	14.83

Column means followed by same letter(s) are not significantly different ($P < 0.05$) using LSD test. * % oviposition inhibition= [(Lc-Lt) /Lc] x100 (where Lc =No. of eggs laid on control, and Lt = mean number of eggs laid on treated seeds).

20 per cent AE at 50 °C or 100 °C recorded the lowest egg load. However, no significant difference was observed between the 10 per cent AE at 50 °C and 10 per cent AE at 100 °C, and between the 20 per cent AE at 25 °C and 20 per cent AE at 50 °C treatments. Percentage oviposition inhibition was highest on seeds treated with 20 per cent AE at 100 °C, and lowest on the 10 per cent AE at 25 °C.

Table 2 shows the effects of the various extracts on the emergence of *C. maculatus* progenies from treated seeds. The results indicated that the 10 per cent AE at 25 °C treatment recorded more progeny emergence than the rest of the treatments. However, the difference between 10 per cent AE at 50 °C and 10 per cent AE at 25 °C was not significant. Also, no significant differences were observed among the 10 per cent AE at 50 °C up to the 20 per cent AE at 25 °C treatment. Significantly higher numbers of progenies emerged from the 20 per cent AE at 25 °C treatment than from 20 per cent AE at 50 °C. However, progeny emergence from the 20 per cent AE at 50 °C and 20 per cent AE at 100 °C were statistically similar to that of Pirimiphos-methyl. Percentage progeny emergence among the treatments was highest in the 10 per cent AE at 25 °C, and lowest in the 10 per cent AE at 100 °C.

Developmental period and adult longevity

The period of development from egg to adult *C. maculatus* was found to range between 21 days on the untreated seeds to 25 days on the 20 per cent AE at 100 °C treatment (Table 3). The results showed that eggs laid on seeds treated with 20 per cent AE at 50 °C, 20 per cent AE at 100 °C or Pirimiphos-methyl took significantly shorter time to emerge as adults compared to the other treatments. However, the difference in egg to adult developmental period did not vary significantly among the control, 10 per cent AE at 25 °C, 10 per cent AE at 50 °C, 10 per cent AE at 100 °C and 20 per cent AE at 25 °C treatments. The mean adult life of the emerged beetles was also found to range from 14 h in the control to 3 h in the 20 per cent AE at 100 °C or Pirimiphos-methyl treatments (Table 3). Adult bruchids emerging from seeds treated with 10 per cent AE at 25 °C, 50 °C and 100 °C took significantly longer time to die compared to those emerging from seeds treated with 20 per cent AE at 25 °C, 50 °C, 100 °C and Pirimiphos-methyl (Table 3). Adult longevity was significantly higher in the untreated seeds than in any of the insecticide treatments. Aqueous extract treatments at 20 per cent concentration were comparable to Pirimiphos-methyl in promoting longevity of the emerged bruchids.

TABLE 2

The Effects of Aqueous Extracts (AE) from Foliage of H. spicigera *Lam. at Different Concentrations and Temperatures on the Emergence of* C. maculatus *Progenies from Kersting's Groundnut Seeds*

Treatment	*No. of progenies emerged*	*Per cent progeny emergence*
Control	97.2 ± 4.19 a	80.3 ± 3.5 a
10% AE at 25 °C	28.0 ± 1.6 b	54.5 ± 2.3 b
10% AE at 50 °C	20.0 ± 1.3 bc	43.9 ± 2.0 b
10% AE at 100 °C	18.5 ± 0.7 c	32.8 ± 1.8 c
20% AE at 25 °C	18.2 ± 0.9 c	51.2 ± 2.4 b
20% AE at 50 C°	7.5 ± 0.6 d	36.5 ± 2.0 bc
20% AE at 100 C°	5.0 ± 0.3 d	35.7 ± 2.0 c
Pirimiphos-methyl	5.0 ± 0.3 d	26.3 ± 1.5 c
LSD ($P < 0.05$)	10.20 10.80	

Column means followed by same letter(s) are not significantly different ($P < 0.05$) using LSD test.

TABLE 3

The Effects of Aqueous Extracts (AE) from Foliage of H. spicigera *Lam. at Different Concentrations and Temperatures on the Egg-adult Developmental Period, and Longevity of Emerged Adults of* C. maculatus *from Kersting's Groundnut Seeds*

Treatment	*Mean developmental period (days)*	*Mean adult longevity (hours)*
Control	21.0 ± 0.5 a	14.0 ± 1.0 a
10% AE at 25 °C	21.6 ± 0.4 a	10.0 ± 0.9 b
10% AE at 50 °C	22.5 ± 0.6 a	9.5 ± 0.8 b
10% AE at 100 °C	23.5 ± 1.0 ab	8.0 ± 0.5 b
20% AE at 25 °C	22.5 ± 0.7 a	4.8 ± 0.2 c
20% AE at 50 °C	24.5 ± 1.0 b	3.5 ± 0.2 c
20% AE at 100 °C	25.2 ± 1.2 b	3.0 ± 0.1 c
Pirimiphos-Methyl	24.2 ± 0.9 b	3.0 ± 0.1 c
LSD ($P < 0.05$)	2.34	3.05

Column means followed by same letter(s) are not significantly different ($P < 0.05$) using LSD test.

Seed damage and viability

Table 4 shows the damage incidence caused by *C. maculatus* on the treated seeds. The results indicated that the mean number of exit holes on the seeds did not vary significantly among the 10 and 20 per cent extract treatments. However, seeds treated with the 20 per cent AE recorded significantly lower numbers of exit holes on seeds compared to those of the 10 per cent AE. The untreated seeds, and those treated with Pirimiphos-methyl contained the highest and lowest numbers of exit holes, respectively.

Percentage weight loss in the seeds was found to be highest in the control and lowest in the Pirimiphos-methyl treatment, with significant difference between them. Seed weight loss did not vary significantly except those treated with 20 per cent AE at 100 °C which had the lowest weight loss. However, weight loss in seeds treated with 20 per cent AE at 100 °C showed no significant difference from those of 20 per cent

TABLE 4

The Damage Incidence caused by C. maculatus *on Kersting's Groundnut Seeds Treated with Aqueous Extracts (AE) from Foliage of* H. spicigera *at Different Concentrations and Temperatures*

Treatment	*Mean No. of exit holes on seeds*	*% weight loss(g) in seeds*
Control	25.0± 1.2 a	15.2± 1.5 a
10% AE at 25 °C	14.7± 0.8 b	8.7± 0.8 b
10% AE at 50 °C	13.0± 0.5 b	8.0± 0.7 b
10% AE at 100 °C	12.6± 0.5 b	7.0± 0.5 b
20% AE at 25 °C	9.5± 0.4 c	6.8± 0.3 b
20% AE at 50 °C	7.4± 0.2 c	6.0± 0.3 b
20% AE at 100 °C	7.0± 0.2 c	5.7± 0.2 b
Pirimiphos-methyl	3.8± 0.1 d	2.3± 0.2 c
LSD ($P < 0.05$)	3.18	3.20

Column means followed by same letter(s) not significantly different ($P<0.05$) using LSD test.

AE at 50 °C or 100 °C.

The results also showed that viability of the Kersting's groundnut seeds was significantly reduced by treatment at 100 °C, but the different concentrations did not show significant reduction in seed viability (Table 5). Also, no significant reduction in percentage seed germination was observed between the control and Pirimiphos-methyl or any of the extracts treated below 100 °C.

Discussion

The study has shown that AEs from *H. spicigera* at different concentrations and temperature treatments were effective at reducing oviposition of *C. maculatus* in Kersting's groundnut grains. The active principle in the seeds probably acted as an effective surface protectant, providing unsuitable host medium for oviposition. This suggests that the insects will prefer untreated seeds to treated seeds for egg laying when there is choice. Obeng-Ofori & Freeman (2001) attributed this to the oviposition deterrence and toxicity of the material to the insects. The reduced number of progenies that emerged from the seeds indicated that the AEs were effective ovicides to the beetles, and inhibiting hatchability of eggs.

Many authors have reported similar findings using *H. spicigera* or other botanicals against *C. maculatus* or other storage insects. Talukder & Howse (1994) showed that the admixture of food with pithraj leaf, bark and seed powder reduced the oviposition rates of *C. maculatus*. Mulatu & Gebremedhin (2000) showed that the oils of neem, milletiaie and pyrethrum were effective at preventing oviposition and progeny emergence of storage beetles. Lale & Mustapha (2000) found no significant difference in the efficacy of neem seed oil and Pirimiphos-methyl in reducing oviposition and adult emergence of *C. maculatus* in treated cowpeas. Sanon *et al.* (2006) reported that essential oils from *H. spicigera* were lethal to *C. maculatus* larvae developing within cowpea seeds; oil activity was age-dependent with younger instars being more susceptible. The 20 per cent foliage extracts from *H. spicigera*, applied at 50 °C or 100 °C were found to offer the best protection from *C. maculatus* infestation in Kersting's groundnut.

The various formulations from *H. spicigera* caused a delayed effect on the egg-adult development of *C. maculatus* on the Kersting's groundnut seeds. The insects took almost 5 additional days to emerge from the treated seeds compared to the untreated seeds. AE from *H. spicigera* is known to contain Pentacyclic triterpenoid compounds such as tannins, sterols

TABLE 5

The Viability of Kersting's Groundnut seeds after Treatment with Aqueous Extracts (AE) from Foliage of H. spicigera *at Different Concentrations and Temperatures*

Treatment	*Initial % seed germination*	*Final % seed germination*
Control	85.0	83.2 ± 1.1 a
10% AE at 25 °C	83.5	83.3 ± 1.5 a
10% AE at 50 °C	86.6	73.3 ± 0.6 a
10% AE at 100 °C	85.4	60.3 ± 0.2 b
20% AE at 25 °C	84.7	83.4 ± 1.3 a
20% AE at 50 °C	84.2	73.0 ± 0.8 a
20% AE at 100 °C	81.8	62.5 ± 0.4 b
Pirimiphos- Methyl	82.0	82.7 ± 1.0 a
LSD ($P < 0.05$)	ns	10.00

Column means followed by same letter(s) are not significantly different ($P<0.05$) using LSD test.

alkanoids, saponin glycocides and flavonoids (Chopra, Nayar & Chopra, 1956), which have membrane lytic activity, having larvicidal effect on the beetles, resulting in prolonged instar moults and delayed larval development. Also, the longevity of the emerged beetles was shortened by the extract treatments. The active principle from the extract caused early death of the adult insects possibly by blocking the tracheal system and causing asphyxiation or anoxia (Osekre & Ayertey, 2002). Extract concentration of 20 per cent treated at temperatures above 50 °C showed more effect on the development and longevity of the insects. Osekre & Ayertey (2002) observed that cowpea grains treated with groundnut oil reduced longevity of emerging adult bruchids.

Sanon *et al.* (2006) reported that crude extracts from *H. spicigera* had a dose-dependent insecticidal effect on emerging progenies of *C. maculatus* on stored cowpea. Othira *et al.* (2009) observed similar findings on newly emerged *S. zeamais* exposed to essential oils from *H. spicigera* in which oils showed strong repellency and high mortality on the weevils. They explained that the differential interspecific insect responses to *H. spicigera* products could be attributed to the compound structure activity-relationships, and physiological structural induced cellular changes resulting in poisoning of the insects by blocking octopamine receptors in adults and larvae (Priestly, Burgess & Williamson, 2006). The results of the study also compared favourably with that of other investigators in which extracts from other Labiatae family plants produced significant fumigant activity against stored-products insects (Shaaya & Kostyukovsky, 2006), nematodes (Yusuf, Hassan & Chris, 2006) and pathogenic microorganisms (Ladan *et al.*, 2009).

The number of exit holes and percentage weight loss in the treated seeds due to *C. maculatus* infestation were significantly reduced in the 20 per cent extract treatment applied at 50 °C or 100 °C, eventhough they were less than the Pirimiphos-methyl treatment. Some larvae that penetrated the treated seeds were not able to emerge as they probably died before their complete development as a result of insecticide poisoning. Also, larval feeding was greatly inhibited leading to reduction of weight loss in seeds, suggesting that the extracts were effective antifeedants to the insects. Raja *et al.* (2000) reported that when pulses were stored in gunny bags treated with AE from leaves of *H. suaveolens,* they effectively protected stored pulses for up to 6 months. The results showed that 20 per cent *H. spicigera* extracts applied at or above 50 °C produced the most residual toxicity to *C. maculatus* in Kersting's groundnut.

The efficacy of the extracts seemed to be more enhanced by the temperature treatments. Obeng-Ofori & Dankwah (2002) recorded significant reduction in seed damage caused by *C. maculatus* in Bambara groundnut grains treated with steam. According to Gatehouse *et al.* (1979), steam or high temperature treatment causes hydrolysis of carbohydrates that are essential for the growth and development of bruchids. Eventhough high temperature treatment was useful in reducing damage of Kersting's groundnut seeds by *C. maculatus*, the process resulted in significant loss of seed viability. Obeng-Ofori & Dankwa (2002) found that most Bambara groundnut seeds did not germinate when treated with vapour steam.

The extract concentrations might not have any significant effect on the viability of the treated seeds. Das (1986) and Keita *et al.* (2001) reported that seeds treated with botanical extract oils did not lose their viability. Onu & Aliyu (1995) reported that though various pepper powders were effective at reducing oviposition and damage caused by *C. maculatus*, seed quality and viability were not affected. Keita *et al.* (2001) reported that powders made from essential oils of different basils provided complete protection against *C. maculatus*, and also did not show significant effect on the seed germination rate.

Conclusion

The study has shown that AE from *H. spicigera* at different temperatures were insecticidal against

C. maculatus. Both the 10 and 20 per cent concentrations applied at the various temperatures were effective, to some degree in reducing *C. maculatus* infestation and damage in Kersting's groundnut. The 20 per cent extract applied at 50 °C or 100 °C proved to be the most effective botanical treatment, and, sometimes, comparable to that of the synthetic insecticide, Pirimiphos methyl, even though application of this at 100 °C reduced the viability of the treated seeds. Farmers can use the 20 per cent *H. spicigera* extract at 100 °C for safe storage of seeds meant for consumption, but for seeds meant for use as planting materials, the extract should be applied at 50 °C or below.

The study has shown a possible scientific rationale for incorporating *H. spicigera* into the grain protection practices for Kersting's groundnut. Its use could also be a viable alternative for protecting seeds of other pulses such as cowpea and Bambara groundnut against bruchid infestation in storage. This indicates a very practical consequence for small-scale subsistence farmers who may be persuaded to replace synthetic insecticides with such plant-derived products for achieving effective, economical, safe and sustainable protection of their stored grains from bruchid infestation and damage. Currently, investigations are on-going for the possibility of further enhancing the efficacy and residual toxicity of the product through combination with vegetable oils in simple synergistic mixtures. A comprehensive evaluation of the product through farmers' field fora has been initiated to confirm the practicability, adoptability and sustainability for protection of grains in the field.

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