Field evaluation of neem seed extract for the control of major pests of cowpea in northern Ghana

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ABSTRACT

Field studies were conducted at the Experimental Farm of the Savanna Agricultural Research Institute (SARI), Nyankpala, northern Ghana, during the 2006 cropping season to evaluate the effect of aqueous neem (*Azadirachta indica* A. Juss) seed extract at 5, 10, 15 and 20 per cent on *Aphis craccivora* Koch., *Megalurothrips sjostedti* Tryb., *Maruca vitrata* Fab., and a complex of pod and seed-sucking bugs of cowpea (*Vigna unguiculata* L. Walpers), as well as their effect on the grain and fodder yields of the crop. The results showed that the incidence and abundance of all the target insect pests were significantly affected by the neem extract treatments. Cowpea grain yield was significantly higher in all the neem-treated plots than in the control. The 15 per cent neem seed extract treatment proved as effective as that of the 20 per cent in increasing the grain yield of the cowpea crop. However, none of the neem treatments was as effective as the synthetic insecticide (Karate) in cowpea grain yield. However, grain quality for the 15 and 20 per cent treatments was similar to that for the Karate treatment. Cowpea fodder yield was found to decrease with increasing concentration of the neem extract. Benefit-cost analysis for the grain and fodder yields showed that the 15 and 5 per cent neem extract treatments, respectively, had the best benefit-cost ratios. Therefore, the 15 per cent neem seed extract is recommended for use in controlling the major field insect pests of cowpea for maximum grain yield in the Guinea savanna agroecological zone of Ghana. However, for situations in which the grower is strapped for cash or neem seeds are inadequate, the 5 or 10 per cent extract may be used. The 5 per cent neem seed extract is recommended for dual-purpose cowpea cultivars for maximum returns on grain and fodder yield.

RÉSUMÉ

BADII, B. K., ASANTE, S. K. & AYERTEY, J. N.: *Évaluation de champ d'extrait de graine de neem pour le contrôle des parasites d'insecte importants de niébé au nord du Ghana.* Des études sur le terrain ont été conduites à la ferme expérimentale de l'Institut de Recherche Agronomique de la Savane (IRAS), de Nyankpala, au nord du Ghana, pendant la saison 2006 d'emblavage, pour évaluer l'effet de l'extrait aqueux de graine de neem (*Azadirachta indica* A. Juss) à 5, 10, 15 et 20% sur *Aphis craccivora* Koch., *Megalurothrips sjostedti* Tryb., *Maruca vitrata* Fab., et un complexe de cosse- et graine-sucer de punaises, de niébé (*Vigna unguiculata* L. Walpers), ainsi que leur effet sur les rendements de grain et de fourrage de la plante. Les résultats ont prouvé que l'incidence et l'abondance de touts les parasites d'insecte de cible ont été sensiblement affectées par le traitement d'extrait de neem. Le rendement de grain de niébé était sensiblement plus haut dans toutes les parcelles de terrain qui ont été traites avec le neem que dans le témoin. Le traitement d'extrait de graine de neem de 15% a prouvé aussi efficace que cela de 20% en augmentant le rendement de grain de la récolte de niébé. Cependant, aucun des traitements de neem n'était aussi efficace que l'insecticide synthétique (karate) en termes de rendement de grain de niébé. La qualité de grain obtenue à partir du 15 et du traitement de 20% était cependant, semblable à cela obtenu à partir du traitement de karate. D'une part, le rendement de fourrage de niébé s'est avéré pour diminuer avec l'augmentation de la concentration des traitements d'extrait de neem. L'analyse d'avantage-coût du grain et les rendements de fourrage ont indiqué que le traitement d'extrait de neem de 15 et de 5%, respectivement, a donné les meilleurs rapports d'avantage-coût. Par conséquent, l'extrait de graine de neem de 15% est recommandé pour l'usage en commandant les parasites d'insecte principaux de champ du niébé pour le rendement maximum de grain dans la zone agroecologique de la savane de Guinée du Ghana. Cependant, dans les situations où le cultivateur n'a pas assez d'argent ou quand des graines de neem ne sont pas suffisantes, l'extrait de 5 ou de 10% peut être employé. D'une part, l'extrait de graine de neem de 5% est recommandé pour les cultivars de niébé à double usage pour des retours maximum sur le grain et le rendement de fourrage.

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Introduction

Cowpea, *Vigna unguiculata* (L. Walpers), is one of the most important grain legumes widely cultivated in the tropics for human consumption, as livestock feed, and for soil nitrogen enrichment (Singh & van Emden, 1979). Although cowpea is widely grown in Ghana, commercial production is restricted to some parts of the Volta, Northern, Upper East, Upper West, and Brong-Ahafo regions (Tweneboah, 2000). One major constraint to the increased and sustainable production of cowpea is damage caused by insect pests (Singh *et al*., 1990). Among the most serious field insect pest species that infest cowpea in the Guinea savanna agroecological zone are the black cowpea aphid, *Aphis craccivora* Koch (Homoptera: Aphididae); the cowpea flower thrips, *Megalurothrips sjostedti* Tryb. (Thysanoptera: Thripidae); the legume pod borer, *Maruca (testulalis) vitrata* Fab. (Lepidoptera: Pyralidae); and a complex of pod and seed-sucking bugs such as *Riptortus dentipes* Fab. (Heteroptera: Alydidae), *Clavigralla tomentosicollis* Stal., *Anaplocnemis curvipes* Fab., *Mirperus jaculus* Fab. (Heteroptera: Coreidae), and *Nezara viridula* L. (Heteroptera: Pentatomidae) (Jackai & Daoust, 1986).

The use of synthetic pesticides in controlling these pests has often generated more problems than provided solutions (Ascher, 1993; Karungi *et al.*, 2000). Although sources of resistance to some insect pests of cowpea have been identified, improved cultivars resistant to these insect pests are not yet widely available to growers (Saxena & Kidiavai, 1997). Alghali (1992) reported that the use of cowpea varieties resistant to insect pests did not contribute to any significant reduction in yield loss. Other bio-intensive strategies, such as biological control and habitat management by using mixed cropping systems, or establishing trap crops have been proposed, but their effectiveness seems to be site, season, crop, or pest-specific (Kyamanywa, Balidawa & Ampofo, 1993; Ampong-Nyarko, Reddy & Saxena, 1994; Ezueh & Taylor, 1994). Because of these concerns, there has been the need to develop more locally available, environmentally friendly, and socio-economically sustainable pesticides, especially those of botanical origin.

Different investigators have recommended different concentrations of the aqueous seed extract from the neem tree, *Azadirachta indica* A. Juss (Meliaceae), for controlling the major field insect pests of cowpea. For instance, it has been demonstrated in Eastern Nigeria that 5 and 10 per cent concentrations of the seed extract significantly reduced pod damage by insect pests (Emosairue & Ubana, 1998). Also, at the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, 10 per cent aqueous seed extract has been considered as the recommended concentration for most field trials against cowpea insect pests (Jackai, Inang & Nwobi, 1992). Although in northern Ghana, Tanzubil (2000) evaluated aqueous neem seed extract at 5 and 10 per cent and reported that the 10 per cent extract was more efficacious against flower thrips, pod borers and pod-sucking bugs, the cowpea pest control recommendation at the Savannah Agricultural Research Institute (SARI) has now been based on the 5 per cent extract, and this has been extended to farmers through IPM Farmer Field Schools. However, farmers in some localities have reported cases of unsatisfactory results from using 5 per cent seed extract (Asante, Personal Communication). Therefore, the need is to standardize the concentration of aqueous extract from the neem seed for controlling the major field insect pests of cowpea in the savanna agroecological zone of Ghana.

This paper reports on the most cost-effective concentration of aqueous neem seed extract that can be used to effectively control the major field insect pests of cowpea for maximum economic returns in the northern Guinea savanna agroecological zone of Ghana.

Materials and methods

Study site, field layout, treatments and planting

The study was at the Experimental Farm of the CSIR-Savanna Agricultural Research Institute (SARI), Nyankpala, in the northern Guinea savanna agroecological zone of Ghana, during the main cropping season (May-October) in 2006. The field was laid out in a randomized complete block design (RCBD). A total of 24 subplots, each measuring 7 m by 6 m with inter-row spacing of 0.75 m and intra-row spacing of 0.25 m , were used. Six treatments, each with four replicates, were applied; namely control (water), 5, 10, 15 and 20 per cent concentrations (w/v) of aqueous neem seed extract, and Karate (Lambda-cyhalothrin) at 36 g ai ha^{-1}.

An improved high-yielding 68-day maturing cowpea variety, Sul 518-2 (Marfo-tuya), collected from the Plant Breeding Unit of the SARI, was used. Sowing was done during the 3rd week of July (i.e. 20th July 2006), a time of the cropping season generally considered most appropriate for covering the peak incidence of all the major insect pests of cowpea in northern Ghana (Tanzubil, 1991). Four seeds were sown per hill and later thinned to two plants per stand 2 weeks after sowing (this measure was to ensure > 95 per cent germination).

Preparation of neem seed extract and application of treatments

Mature neem seeds were collected from the ground under neem trees within the residential area of CSIR-SARI Research staff. The extracts were prepared a day before being applied during each treatment. The extraction method described here was chosen because of its simplicity, ease of adoption, and convenience of use by the local farmers. Six hundred grams seed weight (half local "koko" bowl) was pounded into fine powder using a wooden mortar and a pestle. About 10 g of "key soap" (a detergent) was added to the content to enhance the adhesiveness of the active ingredient and to reduce its volatile effect in the field (Schmutterer, 1988). The powdered mass was soaked in 15 l of water. The content was then stirred and allowed to stay overnight (12 h), after which it was strained over a standard sieve of fine nylon mesh (70 µm). The solution collected was the 5 per cent concentrated solution (w/v) of the extract. Following the same principle, the 10, 15 and 20 per cent concentrations were prepared using 1,200 g neem seed powder (NSP) in 15 l of water; 1,800 g NSP in 15 l of water and 2,400 g NSP in 15 l of water, respectively (Dreyer, 1984).

Treatments were applied at weekly intervals beginning from the 3rd week after plant emergence, using the CP 15 knapsack sprayer. The water and neem treatments were applied at 26, 34, 42, and 50 days after emergence (DAE); whereas the Karate treatment was applied at 26 and 47 DAE. All plants in each subplot were sprayed until they were completely covered or wet. Any spray application that was followed by a significant rainfall within 6 h after spraying was repeated the day after the rain (Passerini & Hill, 1993).

Sampling for insect pests and degree of infestation

Sampling for insect pests and extent of their infestation was carried out 2 days after each insecticide treatment. Six inner rows, excluding 1m border from both ends of each row, were selected from each subplot for sampling. Sampling involved visual examination of each plant for target insects, namely *A. craccivora, M. sjostedti, M. vitrata, C. tomentosicollis, M. jaculus, N. viridula, A. curvipes,* and *R. dentipes*. All plants in the selected six middle rows were counted and visually examined between 25 and 44 DAE to record the number of plants infested by aphids (i.e. abundance); and then scored for severity or degree of infestation (i.e. incidence) on a 0-9 scale, where 0 = no aphids, 1 = 1-4 aphids, 3 = 5-20 aphids, 5 = 21-100 aphids, 7 = 101-500 aphids, and 9 = > 500 aphids per subplot (Jackai & Singh, 1988). Thrips infestation was assessed between flower bud initiation and 50 per cent podding stage. Beginning from flower bud initiation (40 DAE) to 50 per cent flowering (48 DAE), 20 racemes (flower buds) were sampled from each subplot and kept in vials containing 50 per cent ethanol. Also, beginning from 50 per cent flowering to first pod maturity (55 DAE), 20 flowers were sampled and kept in vials containing 50 per cent ethanol. The number of thrips (nymphs and adults) in each sample was then counted under binocular microscope in the laboratory to determine the abundance of thrips on the plants.

Pod borer infestation was also assessed between 50 per cent flowering and first pod maturity. Ten flowers from each subplot were picked at random and kept in vials with 50 per cent ethanol. These were also examined in the laboratory to record the abundance (number) of pod borer larvae on the plants. Concurrently, proportions of flowers infested by pod borers were estimated using the Rapid Visual Examination (RVE) method, whereby 10 flowers were collected at random from each subplot, opened on the spot and examined for pod borer larvae or damage (Jackai *et al*., 1992). The RVE method was also applied to the mature pods to determine the extent of pod borer incidence (damage) on the plants. Pod-sucking bug (PSB) infestation was assessed between the podding and harvest stages. Adults and nymphs of the different PSB species were counted visually on rows of cowpea plants within the marked area in each subplot. These were then recorded for PSB abundance. Counting was done between 1400 and 1700 h (Hammond, 1983). Also, the matured pods were sampled and examined visually to determine the number of shrivelled pods caused by PSB infestation (i.e. incidence).

Yield and quality estimation

Grain yield. Dry grain yield (in kilogrammes per unit area) was estimated after the pods were harvested, sun-dried to 12 per cent moisture content, threshed, and winnowed to obtain the pure seeds. The results were then extrapolated to kilogrammes per hectare for each treatment using the following formula proposed by Asante, Tamo & Jackai (2001):

$$\text{Grain yield ha}^{-1} = \frac{10,000}{\text{Area harvested}} \times \text{Grain yield plot}^{-1}$$

*Grain quality***.** Grain quality estimation was based on a visual grain damage rating scale of 1-6, where 1 = 0-5 per cent damaged grains, 2 = 6-25 per cent damaged grains, 3 = 26-50 per cent damaged grains, 4 = 51-75 per cent damaged grains, 5 = 76-95 per cent damaged grains, and 6 = > 95 per cent damaged grains (Passerini & Hill, 1993). Damaged grains were counted to include all cowpea grains whose quality had been reduced as a result of infestation by the insect pests being considered.

*Fodder yield***.** All plants within the six middle rows of each subplot were uprooted, sun-dried, and weighed using a standard weighing scale. The results of the plant biomass weights for each treatment were extrapolated to kilogrammes per hectare using the following formula (Asante *et al*., 2001):

$$\text{Fodder yield ha}^{-1} = \frac{10,000}{\text{Area harvested}} \times \text{Fodder yield plot}^{-1}$$

Profit per yield and benefit-cost analysis. Partial budgeting was used to estimate the profit per hectare for each treatment. Profit was estimated by deducting total pest control cost from the income derived from the differences in yield above the control. Cost of land preparation, sowing, and weed control were not included in the partial budgeting. Benefit-cost ratio, defined as the number of times the insecticide (synthetic and botanicals) control cost would be recouped from the value of the increase in yield of cowpea, was calculated as:

$$\text{Benefit-cost ratio} = \frac{\text{Value of increased yield}}{\text{Cost of pest control}}$$

Statistical analysis. Differences in infestation by the insect pests, grain and fodder yields between the treatments were examined by subjecting all data to Analysis of Variance (ANOVA) of the randomized complete block design. Where ANOVA indicated significant difference between treatments, the Least Significant Difference (LSD) test was used to separate the treatment means at 5 per cent level of significance. Also, the Student t-test was used to compare the abundance of nymphal and adult thrips in the cowpea flowers.

Results

Major insect pests

The major insect pests met in the field included the black cowpea aphid, *Aphis craccivora* Koch., the cowpea flower thrip, *Megalurothrips sjostedti* Tryb., the legume pod borer, *Maruca vitrata* Fab., and the pod and seed-sucking bug complex identified as *Clavigralla tomentosicollis* Stal., *Anoplocnemis curvipes* Fab., *Mirperus jaculus* Fab., *Riptortus dentipes* Fab., and *Nezara viridula* L.

Aphis craccivora *Koch*

Table 1 presents the effect of the different concentrations of the neem seed extract on the incidence and abundance of *A. craccivora.* The results showed that there was a significant difference between the treatment means in the abundance (F = 23.6, df = 5, 15, $P < 0.01$) and in the severity of infestation (F = 15.2, df = 5, 15, $P < 0.01$). Percentage of plants infested in all neem-treated plots was significantly lower than that of the control, but significantly higher than that of the Karate-treated plot. Among the neem treatments, the 5 per cent neem-treated plot recorded a significantly higher percent infestation than the 10 - 20 per cent treatments, but differences between the 10, 15, and 20 per cent neem treatments were not statistically significant. Mean aphid score from the 5 per cent neem-treated plot also differed significantly from that of the 10 - 20 per cent neem-treated plots, whereas differences were not observed between the 10, 15 and 20 per cent neem treatments.

Megalurothrips sjostedti *Tryb.*

There was a significant difference among the treatment means of *M. sjostedti* in racemes (F = 279.9, df = 5, 15, $P < 0.001$) and flowers (F = 245.7, df = 5, 15, $P < 0.001$). Number of thrips per raceme was significantly lower in all the neem-treated plots than in the control, but significantly higher than that of the Karate-treated plot. Among the neem treatments, number of thrips per raceme was significantly higher in the 5 than in the 10 per cent. The 10 per cent treatment was also significantly higher than the 15 and 20 per cent, whereas differences were not observed between the 15 and 20 per cent neem treatments (Table 1).

Moreover, number of thrips per flower was significantly lower in all the neem-treated plots than in the control. The mean number of thrips decreased significantly with increasing concentration of neem, except the 15 and 20 per cent, which were not significantly different. Generally, the population of adult thrips in racemes and flowers was higher than that of nymphal thrips in all the insecticide-treated plots, whereas the population of adult thrips was found to be lower than that of the nymphs in the control. Thus, insecticide application seemed to have more effect on the nymphs than on the adult thrips.

Maruca vitrata *Fab.*

Table 2 presents the effects of the different neem extract concentrations on the incidence and abundance of the legume pod borer, *M. vitrata*, on the cowpea flowers and pods. There were significant differences among the treatment means of *M. vitrata* larvae infesting the flowers. Number of larvae per flower decreased

TABLE 1

Effect of Neem Seed Extract (NSE) and Karate on Incidence and Abundance of A. craccivora *and* M. sjostedti *During 2006 Cropping Season at Nyankpala, Northern Region, Ghana*

Treatment	*Percentage of plants infested by aphids*	*Mean aphid score[1]*	*Mean no. of thrips per 10 racemes*			*Mean no. of thrips per 10 flowers*		
			Adult	*Nymph*	*Total*	*Adult*	*Nymph*	*Total*
Control	36.6	3.0	22.0	35.2	57.2	22.0	36.0	58.0
5% NSE	10.5	2.2	19.1	16.2	35.3	20.0	17.0	37.0
10% NSE	6.7	1.7	15.0	123.5	27.5	11.0	9.0	20.0
15% NSE	6.3	1.4	10.5	9.0	19.5	7.0	5.5	12.5
20% NSE	5.5	1.1	7.6	6.9	14.5	5.5	4.0	9.5
Karate	1.6	0.2	3.3	2.2	5.5	2.5	0.5	3.0
LSD (5%)	1.50	0.50			6.00			4.88

Mean severity of infestation (i.e. visual rating of the extent of infestation) using a 0-9 rating scale, where 0 = no aphids, 1 = 1-4 aphids, 3 = 5-20 aphids, 5 = 21-100 aphids, 7 = 101-500 aphids, and 9 = >500 aphids (Jackai & Singh, 1988).

TABLE 2

Effect of Neem Seed Extract (NSE) and Karate on Incidence and Abundance of M. vitrata *Larvae to Cowpea Flowers and Pods During 2006 Cropping Season at Nyankpala, Northern Region, Ghana*

Treatment	*Mean no. of larvae per 10 flowers*	*Proportion (%) of flowers infested by larvae*	*Mean no. of damaged pods (n = 6)*	*Proportion (%) of damaged pods*
Control	27.0	72.5	3.1	72.8
5% NSE	16.0	47.5	3.6	44.1
10% NSE	9.5	38.7	3.4	33.6
15% NSE	2.8	23.7	2.2	13.7
20% NSE	2.3	20.0	2.0	12.2
Karate	1.0	12.5	1.4	7.5
LSD (5%)	3.90	9.00	1.00	15.70

n = number of plants sampled

significantly with increasing concentration of neem from 5 to 20 per cent ($F = 107.8$, df = 5, 15, $P < 0.001$). However, significant differences were not observed among the 15 and 20 per cent, and the Karate, although mean values decreased with increasing concentration.

The proportion of flowers infested by the larvae was also found to differ significantly among the treatments ($F = 66.7$, df = 5, 15, $P < 0.001$). Among the neem treatments, the 5 per cent recorded a significantly higher percentage flower infestation than the 10 per cent, which in turn recorded a significantly higher percentage infestation than the 15 per cent. The 15 and 20 per cent as well as the Karate treatment were not significantly different.

Also, significant differences were observed among the treatment means of pods damaged by

M. vitrata (F = 9.8, df = 5, 15, $P < 0.001$). The number and proportion of damaged pods were found to decrease with increasing concentration of neem. Although differences between the 15 and 20 per cent neem and Karate-treated plots were not statistically significant, the Karate-treated plot recorded the lowest percentage of damaged pods.

Pod-sucking bugs (PSBs)

The incidence and abundance of PSBs was significantly affected by the different concentrations of neem (F = 66.4, df = 5, 15, $P < 0.001$; F = 4.9 and 52.3, df = 5, 15, $P < 0.001$). The population of each species of PSBs, as well as the number of shrivelled pods was found to decrease significantly with increasing neem concentration up to 15 per cent. Moreover, the proportion of shrivelled pods decreased significantly from 5 to 20 per cent (F = 52.3, df = 5, 15, $P < 0.001$) (Table 3).

Grain and fodder yields

Table 4 shows the effects of the different concentrations of the neem extract on the grain and fodder yields, and grain quality of the cowpea crop. Cowpea grain yield and quality were significantly affected by the treatments applied ($P < 0.05$). Grain quality from the 20 per cent extract was found to be similar to that of the synthetic insecticide (Karate). In contrast to grain yield, cowpea fodder yield decreased significantly with increasing neem concentration (F = 10.4 df = 5, 15, $P < 0.001$). Fodder yield was also found to decrease considerably by applying the synthetic insecticide. The control and Karate-treated plot recorded the highest and lowest fodder yields, respectively.

Benefit-cost ratio

Table 5 presents the profit per hectare and benefit-cost ratios for the grain and fodder yields of the cowpea crop. Partial budgeting has shown that the profit per hectare from the cowpea grain increased with increasing concentration of neem from 5 to 15 per cent; further increase in concentration provided a decrease in profit. Each neem treatment was found to provide a higher profit than the control, but a lower profit than the Karate treatment.

Partial budgeting from fodder yield showed that profit per hectare decreased with increasing concentration of neem. All neem treatments provided a lower profit than the control, but a higher profit than the Karate treatment. Benefit-cost ratio also decreased with increasing

TABLE 3

Effect of Neem Seed Extract (NSE) and Karate on Incidence and Abundance of Pod-sucking Bugs (PSBs) on Cowpea Plants During 2006 Cropping Season at Nyankpala, Northern Region, Ghana

Treatment	*Mean number of PSBs per 5 m row of cowpea*						*Mean number of shrivelled pods*	*Proportion of shrivelled pods*
	R. dentipes	C. tomento-sicollis	A. curvipes	N. viridula	M. jaculus	*Total*		
Control	9.3	7.5	6.2	5.5	3.0	31.5	2.9	85.4
5% NSE	6.0	4.0	4.0	3.8	2.8	20.6	3.6	67.7
10% NSE	4.8	4.0	3.0	2.2	2.0	16.0	2.8	28.0
15% NSE	4.5	3.0	2.5	2.0	1.8	13.8	1.7	11.2
20% NSE	3.6	2.8	2.2	2.0	1.5	12.1	2.2	10.5
Karate	2.0	1.5	1.3	1.36	0.5	6.6	1.7	8.5
LSD (5%)	0.65	0.82	0.45	0.50	0.45	2.52	0.83	12.50

TABLE 4

Effect of Neem Seed Extract (NSE) and Karate on Cowpea Grain Yield and Quality During 2006 Cropping Season at Nyankpala, Northern Region, Ghana

Treatment	*Mean number of pods per plant (n = 6)*	*Mean grain yield (kg ha^{-1})*	*Mean rating of damaged grains[1]*	*Mean fodder yield (kg ha^{-1})*
Control	3.4	203.3	4.8	2442.5
5% NSE	5.4	408.0	3.5	1851.8
10% NSE	10.0	709.0	3.0	1359.5
15% NSE	15.1	1455.5	2.7	806.0
20% NSE	15.9	1471.5	2.4	791.5
Karate	17.0	1698.3	2.3	494.0
LSD (5%)	1.95	85.0	0.45	600.0

n = number of plants sampled for pod count
[1]Damaged grains include all cowpea seeds whose quality has been reduced as a result of infestation by the field insect pests. Grain damage rating was based on a visual scale of 1-6, where 1 = 0-5%, 2 = 6-25%, 3 =26-50%, 4 = 51-75%, 5 = 76-95%, and 6 = >95%.

TABLE 5

Benefit-cost Analysis From Cowpea Grain and Fodder Yields Obtained from Nyankpala, Northern Region, Ghana, During 2006 Cropping Season

Treatment	*Mean grain and (fodder) yield (kg ha^{-1})*	*Value of yield*		*Cost of treatment*		*Profit per hectare*		*Benefit-cost ratio*
		$	*¢*	*$*	*¢*	*$*	*¢*	
Control	203.3	54.2	488,000	-	-	54.2	488,000	-
	(2442.5)	(108.5)	(977000)			(108.5)	(977000)	(-)
5% NSE	408.0	108.7	978,000	71	64,000	16.1	914,000	14.2
	(1851.8)	(82.3)	(740720)			(75.1)	(676720)	(10.5)
10% NSE	709.0	16.1	1,702,000	14.2	128,000	174.9	1,574,000	12.2
	(1359.5)	(60.4)	(543800)			(46.2)	(415800)	(3.2)
15% NSE	1455.5	388.1	3,494,000	21.3	192,000	366.8	3,302,000	17.1
	(806.0)	(35.8)	(322400)			(14.4)	(130400)	(0.6)
20% NSE	1471.5	392.3	3,531,000	28.4	256,000	363.8	3,275,000	12.7
	(791.5)	(35.2)	(316600)			(6.7)	(60600)	(0.2)
Karate	1698.3	452.8	4,075,900	31.1	280,000	421	3,795,900	13.5
	(495.5)	(22.6)	(198000)			(-9.1)	(-82000)	(-0.7)

Fodder yields are in parenthesis. Exchange rate as at time of study: ¢9,000 = US$1. Selling price for cowpea fodder = ¢400 kg^{-1}. Selling price for cowpea seeds as at time of study: ¢2,400 kg^{-1}. Cost of treatments include only cost of chemicals applied throughout the cropping; cost of neem seed: ¢8,000 kg^{-1}; cost of Karate: ¢70,000 l^{-1} (Source: Market Information Branch, Ministry of Agriculture, Tamale, Ghana).

concentration of the neem. The 5 per cent neem treatment provided the highest ratio while 20 per cent neem extract and Karate treatment provided the lowest.

Discussion

The results of this study showed that different concentrations of neem seed extract were effective at reducing the incidence and abundance of the major field pests of cowpea. The reduction in pest infestation might be due to the repellent, antifeedant, and growth disruptive effects of the neem insecticides on the insects. Schmutterer (1990) reported that neem derivatives usually act as olfactory repellents, antifeedants (phago-terrents), and growth regulators on insect pests, the combined effect of which may lead to considerable decline in their populations. All the neem-treated plants also seemed to show faster rate of leaf senescence and pod drying, compared with those in the control, suggesting that the neem extract had the effect of shortening the maturity period of the cowpea crop.

The results showed that an increase in concentration of neem resulted in reducing the incidence and abundance of *Aphis craccivora* Koch. on the cowpea plants. Lowery, Isman & Brard (1993) reported that seed extracts from neem reduce aphid numbers on pepper and strawberry in a dose-dependent manner. In this study, the neem products acted as effective aphicides even at the lowest concentration of 5 per cent. Exposure of the products to the insects on the cowpea foliage probably led to uptake of the active principles by contact and feeding, suggesting a direct contact toxicity and systemic activity of the products. Stark, Vagas & Thalman (1990) reported that neem seed extract exert contact and systemic effects on aphids, the combined effect of which resulted in nearly 100% insect mortality.

However, the low aphid incidence at the study site could probably be due to the action of rainfall and temperature (Ascher, 1993). The continuous heavy rain experienced during the initial stages of crop growth might have washed away a significant number of aphids from the plants. Also, temperatures were relatively cool during the sampling periods, with average mean daily temperatures between 18.5 and 25.5 °C. Such environment could reduce aphid feeding, mobility and capacity to reproduce; thus, causing a subsequent decline in their populations (Schmutterer, 1990).

The high sensitivity of the nymphal thrips to the neem products could be due to their low mobility and more confined and gregarious feeding habits. Saxena & Kidiavai (1997) observed that thrip nymphs were more prone to the insecticidal effect of neem on cowpea racemes and flowers than the adult thrips because of their large numbers, low mobility, confined habit, and gregarious feeding which may help enhance uptake and translocation of the active principles of the product. Dreyer (1986) reported a significantly fewer number of thrip nymphs on flower buds, less shedding of flower buds, and increased production of pods on cowpea plants sprayed with 5 or 10 per cent aqueous neem seed extract compared with the untreated control, with no significant drop in the number of adult thrips. Foliar spraying with aqueous neem seed extract also significantly reduced the infestation of thrips on cowpea and resulted in higher grain yield compared with the untreated control in Nigeria and Ghana (Ivbijaro & Bolaji, 1990; Tanzubil, 1991). In Tanzania, damage to the cowpea crop was reduced and the population of *M. sjostedti* was suppressed as effectively with aqueous neem seed extract as with Lindane (Hongo & Karel, 1996).

Although complete larval mortality was not recorded for any of the neem concentrations in this study, larval feeding of *M. vitrata* on the cowpea flowers and pods was significantly reduced, and as a result, there was reduced pod damage in all the neem-treated plants compared with the control. The neem derivatives might have acted as feeding deterrents on the insects, to the extent that the larvae might not have fed at all and so died as a result of prolonged starvation. Jackai *et al.* (1992) reported that besides azadirachtin, other products present in neem seed might act as larvicidal, feeding deterrents or suppressants. Butterworth & Morgan (1971) reported an inhibitory effect of neem on the feeding ability of *Schistocerca gregaria* Forst. At low concentrations (5 g 300 ml^{-1} seed extract), azadirachtin prolonged development of the nymphs, which took twice the normal development time to become adults. At higher concentrations, the products either deformed the insects or killed them outright.

Roscoe (1972) also reported prolonged growth of lepidopterous larvae at low rates of azadirachtin, and deformities in the adults or death of the adults or both at high doses. Bottenberg & Singh (1996) reported that higher concentrations and increased number of applications are usually required to improve the positive effects of neem on pod borers infesting cowpea. Jackai *et al*. (1992) found that marginal survival of pod borers on cowpea decreased with increasing concentration of neem from 5 to 15 per cent, after which further increase in concentration produced no significant increase in the survival rates of the insects. This might explain why no significant difference in pod borer incidence was found between the 15 and 20 per cent concentrations of the extracts in this study.

Neem seed extract at concentration of 15 per cent or above proved as effective as the Karate insecticide in reducing the proportion of shrivelled cowpea pods caused by PSBs. Tanzubil (2000) reported that aqueous neem seed extract, even at 10 per cent concentration, was as effective as Karate insecticide in suppressing the population of PSBs infesting cowpea plants in northern Ghana. The neem treatments in this study probably repelled the bugs on approaching the treated plants, as they seemed to show negative piercing and sucking responses by initially flying away before alighting on the treated pods to attempt feeding. This might have led to prolonged starvation and, therefore, increased mortality. Similar behavioural manifestations were reported by Jackai *et al.* (1992) for *C. tomentosicollis* Stal. on cowpea. Abdulai, Shepard & Mitchel (2002) also observed that male and female *N. viridula* showed similar feeding behavioural patterns on neem-treated cowpea pods, and Bowling (1980) observed similar patterns for other pod suckers infesting soybean. Despite the slow speed of kill, the growth disruptive effects of neem on the instar nymphs of the bugs have been reported to reduce their capacity to damage crops several days before their death (Jackai *et al.,* 1992).

The study has shown that cowpea grain yield increased with increased concentration of the neem extract. Increase in grain yield might be due to reduction in the abundance of the major insect pests and their incidence on the cowpea crop. Saxena & Kidiavai (1997) also reported a significantly higher pod yield from cowpea plants treated with 20 per cent neem seed extract compared with the untreated control. Ivbijaro & Bolaji (1990) claimed that although seed yield of cowpea, after treatment with Cypermethrin + Dimethoate, was significantly higher than the yield recorded for neem seed extract treatment, the marginal increase in yield compared with the control was realised by foliar spraying with the extracts from neem.

The neem extract also resulted in a reduced proportion of damaged cowpea grains. Passerini & Hill (1993), in a field trial using locally formulated aqueous neem seed extract, found that neem extract concentration as low as 1 per cent was more effective in reducing the number of damaged grains and increasing grain quality in millet than the untreated control. The 15 or 20 per cent neem seed extract was as effective as the Karate insecticide in reducing the proportion of damaged grains and increasing grain quality in the cowpea. Grain quality in neem-treated cowpea has been higher than that in Cypermethrin (Saxena & Kidiavai, 1997).

The higher fodder yield observed in the control plot over the insecticide-treated plots indicated that maximum fodder yield could be possible even without applying insecticides. The reduced pest incidence and abundance in the insecticide-treated plots possibly provided a more favourable growth environment for the plants. This might have increased the partitioning of much of the plant biomass into pods and seeds, resulting in an increased grain yield with low dry matter content after harvest.

Partial budgeting showed that although the Karate treatment had the highest profit per hectare, the benefit-cost ratio derived from its use was lower than that of 5 or 15 per cent neem extract because of the high cost associated with it. It would, therefore, be more cost-effective to produce cowpea for grains using the 15 - 5 per cent neem seed extract instead of the Karate or 20 per cent neem extract. Saxena & Kidiavai (1997), in a field trial to control flower thrips on cowpea in South Eastern Kenya, recorded a higher net gain from the 5 per cent than from the 20 per cent neem treatment. Emosairue & Ubana (1998) also reported that Karate treatment, though provided the highest yield and highest profit of cowpea grain, it was less cost-effective than the 5 per cent neem extract treatment.

Partial budgeting also showed that for fodder production, it would be more economical to cultivate cowpea using the 5 per cent neem extract treatment. Any further increase in concentration may lead to diminishing returns, resulting in reduced profit.

Conclusion

The study has shown that aqueous extracts from neem seeds have considerable potential for managing the major field insect pests of cowpea in the savanna ecology of Ghana. The incidence and abundance of all the major insect pests indicated a dose-dependent response. Although the levels of control were variable, the 15 and 20 per cent neem seed treatments provided levels of control similar to each other and to the Karate insecticide. Though grain yield derived from any of the neem extract treatments was not as high as that of the Karate treatment, grain quality from the 15 or 20 per cent neem treatment was similar to Karate treatment. Cowpea fodder yield, however, decreased with increasing concentration of the neem extracts.

The 15 per cent neem seed extract is recommended for use in controlling the major field insect pests of cowpea for maximum grain yield in the Guinea savanna agroecological zone of Ghana. However, for situations in which the grower is strapped for cash or enough neem seeds are unavailable, the 5 or 10 per cent extracts may be used. The 5 per cent neem seed extract is recommended for dual-purpose cowpea cultivars or where mixed farming is practiced or both, to help maintain reasonable yields and maximum returns on grain and fodder yield.

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