Field Efficacy of Neem (*Azadirachta indica* A. Juss) for Managing Soil Arthropods and Cercospora Leaf Spots Damage for Increased Yield in Peanut

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Abstract

Abudulai M., Salifu A.B., Opare-Atakora D., Haruna M., Baba I.I.Y., Dzomeku I.K., Brandenburg R.L., Jordan D.L. (2013): **Field efficacy of neem** (*Azadirachta indica* A. Juss) **for managing soil arthropods and Cercospora leaf spots damage for increased yield in peanut**. Plant Protect. Sci., **49**: 65–72.

Field efficacy of neem (*Azadirachta indica* A. Juss) for managing soil arthropods and Cercospora leaf spots damage to peanut was studied in Ghana from 2008 to 2010. Treatments consisted of neem kernel water extract (NKWE) and neem kernel powder (NKP) applied separately as soil drench at the rates of 10.5 and 21.0 kg/ha at either planting or pegging. Untreated control and chlorpyrifos treatment at pegging were included as checks. Results showed generally that the neem products at the concentrations tested were efficacious and comparable to chlorpyrifos in lowering populations of soil arthropods and severity of leaf spot diseases, leaf defoliation, and scarified and bored pod damage, resulting in increased pod yield in 2008 and 2009.

Keywords: *Azadirachta indica* A. Juss; *Arachis hypogeae* L.; leaf spots; pest control

The soil arthropod pests, termite (*Microtermes* and *Odontotermes* spp.), white grubs (*Schyzonicha* spp.), millipedes (*Peridontopyge* spp.) and wireworms (*Heteroligus claudius*), and the foliar diseases, early leaf spot (*Cercospora arachidicola* Hori) and late leaf spot (*Cercosporidium personatum* (Berk. & M.A. Curtis) Deighton) are major constraints to peanut (*Arachis hypogeae* L.) production in Ghana (Umeh *et al.* 2001; Abudulai *et al.* 2007, 2012). The arthropods damage plants by penetrating and feeding on developing pegs, pods, and seeds inside pods, resulting in yield loss ranging between 30% and 70% in West Africa (Johnson *et al.* 1981; Umeh *et al.* 1999, 2001; Abudulai *et al.* 2012). Their feeding activity also predisposes pods to infection by disease pathogens such as the fungus, *Aspergillus flavus* (Link) (Wightman *et al.* 1990; Lynch *et al.* 1991; Waliyar *et al.* 1994). Also, early and late leaf spot diseases that manifest as reddish brown to black necrotic spots on leaves cause premature defoliation and yield loss up to 70% in peanut (Shokes & Culbreath 1997; Waliyar *et al.* 2000). Chemical treatment is the conventional method for control of pests and diseases in peanut (Brandenburg & Herbert 1991; Branch & Culbreath 2008). However, in many developing countries such as Ghana farmers seldom control these pests in their peanut fields, which may be attributed to limited financial resources to use chemical control.

Products of the neem tree (*Azadirachta indica* A. Juss) from all parts of the plant have demonstrated efficacy against many pest species including arthropod pests and diseases of crops. The principal active ingredient, Azadirachtin, is however more concentrated in the kernel, which makes it the most effective part of the plant (Schmutterer 1990; Gahukar 2000). Neem acts on insects in several ways including contact toxicity, repelling adults and larvae, disrupting developmental processes, and disrupting adult behaviour such as mating (Mordue 2004; Isman 2006). Neem also acts systemically because of absorption by roots and translocation to plant parts when applied into soil or sprayed on the plant (Thoeming & Poehling 2006; Thoeming *et al*. 2006). Laboratory and field studies have demonstrated efficacy of neem extracts against soil pests such as termites (Carter & Mauldin 1981; Lin & Wang 1988; Umeh *et al*. 2001; Cherry & Nuessly 2010). Neem has also been reported to inhibit spore germination and mycelial growth of leaf disease fungi (Kale & Holey 1994; Bambawale *et al*. 1995; Gahukar 2000). However, the application of neem extracts for control of soil pests and leaf spot diseases of field peanut is yet to be explored. There is the need to harness the pesticidal activity in this promising natural product that abounds in Ghana and other parts of sub-Saharan Africa for control of peanut pests. Therefore, the objective of this study was to evaluate neem kernel water extract and neem kernel powder for managing soil arthropod pests and Cercospora leaf spot diseases of field peanut for increased yield.

MATERIAL AND METHODS

The study was conducted at the research farm of the CSIR-Savanna Agricultural Research Institute located at Nyankpala (9°42'N, 0°92'W, and 184 m a.s.l.) and on farm at Bagurugu (9°53'N, 0°43'W, and 168 m a.s.l.), both in the northern region of Ghana from 2008–2010 crop seasons. The experimental lay out was a randomised complete block design and treatments were replicated four times. Plots consisted of six rows 5 m long with spacing of 0.4 m between rows and 0.1 m between plants in a row. The peanut cv. Chinese was used and planted on June 25th 2008, June 10th 2009, and June 21st 2010 at Nyankpala and on June 23rd 2008, June 25th 2009, and June 8th 2010 at Bagurugu. Treatments consisted of neem kernel water extract (NKWE) and neem kernel powder (NKP) applied separately each at the rates of 10.5 and 21.0 kg/ha at either planting or pegging stage (50 days after planting) of the crop. Untreated control and the standard treatment at pegging with chlorpyrifos (Brandenburg & Herbert 1991) were included as checks. All treatments were applied into the soil as soil drench along planting rows.

Preparation of neem kernel powder and neem kernel water extracts. Neem kernel powder and extracts were prepared from air-dried seeds collected from neem trees on the research farm at Nyankpala. The dried seeds were decorticated to remove the shells to obtain the kernels. The kernels were then pounded in a mortar using a pestle to obtain the NKP. The NKWE was prepared by soaking the NKP in ordinary tap water and allowed to stand for 24 hours. The mixture was strained through a muslin cloth to obtain the filtrate or extract that was put in a knapsack for spraying. The quantities of NKP were the same as those used to prepare the NKWE for the different concentrations expressed per ha.

Data collection. Randomly selected samples of 5 plants were dug with the associated soil around the root zone for soil arthropod pests. The samples were taken at harvest from within the outer two rows of each plot and data on the numbers of pests on plants and soil samples were recorded. Samples of 100 pods were taken to determine numbers of pods that were scarified (fibrous tissue surrounding pods removed) or bored into by soil pests and were converted to percentages. Severity of early and late leaf spot diseases and percentage defoliation were assessed at harvest on 10 randomly selected plants using the Florida scale of 1–10 where 1 represents no leaf spot and 10 represents plants completely defoliated and killed by leaf spot (Chiteka *et al*. 1997). The middle four rows of each plot were harvested to determine yield.

Statistical analyses. The data were subjected to analysis of variance (ANOVA) using the general linear models procedure of SAS (SAS Institute 1998). Where a significant treatment effect was measured by ANOVA, means were separated using Fisher's protected Least Significance Difference (*LSD*) test at $P < 0.05$. Percentage data for pod damage and defoliation were transformed using arcsin(x) or square root ($x + 0.5$) as appropriate prior to analysis.

RESULTS

Nyankpala. In 2008, chlorpyrifos and *A. indica* treatments, irrespective of whether used as powder or water extract and time of application, significantly ($P < 0.05$) lowered populations of millipedes, white grubs, and termites compared with untreated control (Table 1). In 2009, only

Table 1. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on abundance of soil arthropod pests (Nyankpala, 2008–2010)

Treatment	Rate (kg/ha)	Timing	Millipedes			Whitegrubs			Termites		
			2008	2009	2010	2008	2009	2010	2008	2009	2010
NKWE	10.5	planting	0.0[b]	0.3[bc]	2.0	0.3[b]	0.0	–	0.0[b]	–	0.5
		pegging	0.0[b]	0.0[c]	1.5	0.0[b]	0.8	–	12.5[b]	–	2.5
	21.0	planting	0.0[b]	0.5[a–c]	1.3	0.3[b]	0.0	–	52.5[b]	–	1.5
		pegging	0.0[b]	0.0[c]	0.5	0.0[b]	0.3	–	7.5[b]	–	5.5
NKP	10.5	planting	0.3[b]	0.0[c]	1.5	0.0[b]	0.3	–	3.8[b]	–	0.0
		pegging	0.0[b]	0.3[bc]	0.5	0.0[b]	0.0	–	6.3[b]	–	3.8
	21.0	planting	0.3[b]	0.8[ab]	3.0	0.3[b]	0.5	–	32.5[b]	–	4.0
		pegging	0.0[b]	0.3[bc]	2.0	0.0[b]	0.5	–	0.0[b]	–	0.0
Chlorpyrifos	2.0	pegging	0.3[b]	0.0[c]	0.5	0.0[b]	0.0	–	25.0[b]	–	2.5
Untreated		–	2.3[a]	1.0[a]	2.0	0.8[a]	1.0	–	200.0[a]	–	17.5
P > *F*		–	0.0001	0.0179	0.4630	0.0577	0.1355	–	0.0314	–	0.0933
CV (%)		–	19.1	24.4	39.1	21.6	30.9	–	69.2	–	30.7

– pest was not recorded for the year; means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at $P < 0.05$

millipede populations were generally lowered by the treatments. Populations of millipedes and termites recorded in 2010 were not significantly different ($P > 0.05$) among the treatments (Table 1).

Also, chlorpyrifos and *A. indica* treatments independent of the form used and time of application significantly ($P < 0.05$) lowered severity of both early and late leaf spot diseases, and percentage defoliation compared with untreated control in 2009 and 2010 (Table 2).

In 2008, percentage scarified pods caused principally by termites was significantly ($P < 0.05$) lower in chlorpyrifos and *A. indica* treatments than untreated control (Table 3). Also, percentage bored

Table 2. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on severity of early and late leaf spots, and percentage defoliation (Nyankpala, 2009 and 2010)

Treatment	Rate (kg/ha)	Timing	Early leaf spots		Late leaf spots		Defoliation (%)	
			2009	2010	2009	2010	2009	2010
NKWE	10.5	planting	3.3[b]	4.9[b]	4.3[b]	5.9[b]	61.3[bc]	60.0[bc]
NKWE		pegging	3.3[b]	4.9[b]	4.3[b]	5.9[b]	61.3[bc]	65.0[b]
	21.0	planting	3.3[b]	4.2[de]	4.4[b]	5.2[cd]	63.8[b]	53.8[de]
		pegging	3.3[b]	4.8[b]	4.3[b]	5.8[b]	62.5[b]	58.8[cd]
NKP	10.5	planting	3.3[b]	4.8[b]	4.3[b]	5.8[b]	63.8[b]	61.3[bc]
NKP		pegging	3.3[b]	4.7[bc]	4.4[b]	5.6[bc]	60.0[bc]	57.5[cd]
	21.0	planting	3.1[b]	4.6[bcd]	4.2[b]	5.7[bc]	55.0[c]	58.8[cd]
		pegging	3.2[b]	4.4[cde]	4.3[b]	5.6[bc]	58.8[bc]	56.3[cd]
Chlorpyrifos	2.0	pegging	3.2[b]	4.0[e]	4.2[b]	5.0[d]	58.8[bc]	50.0[c]
Untreated		–	4.2[a]	5.5[a]	5.4[a]	7.2[a]	75.0[a]	75.0[a]
P > *F*		–	< 0.0001	< 0.0001	< 0.0001	< 0.0001	0.0012	< 0.0001
CV (%)			14.3	6.3	11.0	5.7	8.0	6.3

Leaf spot disease severity scores were rated on 10 plants using the Florida scale of 1–10 based on visual observations (Chiteka *et al.* 1997); means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at $P < 0.05$

Table 3. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on percentage scarified and bored pods and pod yield (Nyankpala, 2008–2010)

Treatment	Rate (kg/ha)	Timing	Scarified pods (%)			Bored pods (%)			Pod yield (kg/ha)		
			2008	2009	2010	2008	2009	2010	2008	2009	1010
NKWE	10.5	planting	7.5^{b}	3.8	7.5^{ab}	1.3^{b}	10.3^{bc}	5.3^{bcd}	954.1^{bc}	1615.6	1471.9
		pegging	4.8^{b}	4.0	3.0^{c}	2.5^{b}	10.3^{bc}	7.3^{b}	1013.8^{bc}	1471.9	1543.8
	21.0	planting	7.8^{b}	6.3	8.3^{a}	2.0^{b}	9.0 c	6.3^{bc}	1113.1^{ab}	1521.9	1643.8
		pegging	7.8^{b}	1.8	5.5^{abc}	1.3^{b}	9.8^{bc}	5.5^{bcd}	1016.1^{bc}	1537.5	1559.4
NKP	10.5	planting	7.5^{b}	3.5	7.5^{ab}	1.5^{b}	10.8^{bc}	5.8^{bcd}	1280.0^{a}	1365.6	1637.5
		pegging	4.0^{b}	4.3	5.0^{bc}	3.0^{b}	11.3^{bc}	4.8^{bcd}	1093.4^{ab}	1378.1	1556.3
	21.0	planting	7.0^{b}	4.5	6.5^{ab}	1.8^{b}	6.8^{cd}	4.0^{cd}	1078.9^{ab}	1440.6	1491.7
		pegging	7.0^{b}	2.8	5.5^{abc}	2.5^{b}	12.5^{ab}	5.8^{bcd}	1159.5^{ab}	1521.9	1545.8
Chlorpyrifos	2.0	pegging	7.8^{b}	1.3	3.0^{c}	1.5^{b}	3.5^{d}	2.8^{d}	1138.6^{ab}	1790.6	1565.6
Untreated	–	–	15.3^{a}	7.8	8.5^{a}	8.0^{a}	17.3^{a}	13.5^{a}	800.9^{c}	1440.0	1153.1
P > *F*		–	0.0245	0.1460	0.0058	0.0315	0.0008	< 0.0001	0.0382	0.1227	0.3356
CV (%)			48.2	36.5	35.4	34.1	16.0	36.1	8.0	12.2	16.7

Means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at $P < 0.05$

pods was significantly ($P < 0.05$) lower in treated than untreated plots. Moreover, pod yield was significantly ($P < 0.05$) greater in treated than untreated plots except for plots that were treated with 10.5 kg/ha NKWE or at pegging with 21.0 kg/ha NKWE. Yield generally was higher in chlorpyrifos and the NKP treatments. In 2009, percentage scarified pods was not significantly different ($P >$ 0.05) among the treatments. However, percentage bored pods was significantly ($P < 0.05$) lower in chlorpyrifos and *A. indica* treatments than control except plots that were treated at pegging with 21.0 kg/ha NKP. Pod yield for the year was not significantly different ($P > 0.05$) among the treatments. In 2010, lower percentage scarified pods was recorded in chlorpyrifos and plots treated

Table 4. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on abundance of soil arthropod pests (Bagurugu, 2008–2010)

Treatment	Rate (kg/ha)	Timing	Millipedes			Whitegrubs			Termites		
			2008	2009	2010	2008	2009	2010	2008	2009	2010
NKWE	10.5	planting	0.8^{ab}	0.0	13	0.3	0.3	0.3^{b}	0.0	7.5	12.5
		pegging	0.0^{c}	0.5	0.0	0.0	0.3	0.5^{b}	0.0	0.0	5.0
	21.0	planting	0.8^{ab}	0.5	1.3	0.0	0.3	0.3^{b}	0.0	0.0	0.0
		pegging	0.3^{bc}	0.8	0.3	0.0	0.3	0.5^{b}	0.0	25.0	0.0
NKP	10.5	planting	0.5^{bc}	0.8	0.8	0.3	0.0	0.3^{b}	0.0	0.0	12.5
		pegging	0.3^{bc}	0.5	1.0	0.0	0.3	0.0^{b}	0.0	0.0	0.0
	21.0	planting	0.8^{ab}	0.8	1.0	0.5	0.3	0.0^{b}	0.0	0.0	5.0
		pegging	0.0^{c}	0.5	0.8	0.0	0.5	0.0^{b}	0.0	62.5	5.0
Chlorpyrifos	2.0	pegging	0.0^{c}	0.3	0.5	0.0	0.0	0.0^{b}	0.0	25.0	0.0
Untreated		–	1.5^{a}	1.3	1.0	0.8	1.0	1.3^{a}	12.8	15.0	5.0
P > *F*		–	0.0038	0.4755	0.1141	0.1861	0.2816	0.0065	0.3873	0.4923	0.8697
CV (%)			24.7	32.9	27.7	26.0	27.8	24.0	34.1	87.7	53.3

Means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at $P < 0.05$

at pegging with 10.5 kg/ha NKWE or 10.5 kg/ha NKP compared with untreated control. Also, percentage bored pods was significantly (P < 0.05) lower in chlorpyrifos and *A. indica* treatments compared with control. However, there were no significant differences (P > 0.05) in pod yield among the treatments.

Bagurugu. In 2008, chlorpyrifos and *A. indica* treatments significantly (P < 0.05) lowered populations of millipede compared with control except for plots that were treated at planting with 10.5 or 21.0 kg/ha NKWE or 21.0 kg/ha NKP (Table 4). There were however no significant differences (P > 0.05) among the treatments in populations of white grubs and termites. In 2009, there were no significant differences (P > 0.05) among the treatments in the populations of all the three aforementioned arthropods. In 2010, populations of white grubs were lower in chlorpyrifos and *A. indica* treatments than untreated control. Millipede and termite populations were not significantly different (P > 0.05) among the treatments.

In 2009, significantly (P < 0.05) lower severity of early leaf spots was recorded in chlorpyrifos treatments and plots treated at planting with 10.5 kg/ha NKWE or at either planting or pegging with 21.0 kg/ha NKWE compared with control (Table 5). Also, lower severity of late leaf spots was recorded in chlorpyrifos and *A. indica* treatments than control except for plots that were treated at pegging with 10.5 kg/ha NKWE, or at planting with either 10.5 or 21.0 kg/ha NKP. Nonetheless, percentage defoliation was lower in chlorpyrifos and all *A. indica* treatments. In 2010, severity of both early and late leaf spots and percentage defoliation were lower in chlorpyrifos and *A. indica* treated plots compared with control.

In 2008, percentage scarified pods was significantly (P < 0.05) lower in chlorpyrifos and *A. indica* treatments compared with control except for plots that were treated at planting with 10.5 kg/ha NKP (Table 6). Percentage bored pods was also significantly (P < 0.05) lower in chlorpyrifos and *A. indica* treatments than control. Pod yield during the year was significantly (P < 0.05) higher in chlorpyrifos and *A. indica* treatments than control except for plots that were treated with 10.5 kg/ha NKWE at planting. In 2009, percentage scarified pods and percentage bored pods were significantly (P < 0.05) lower in chlorpyrifos and *A. indica* treatments compared with control (Table 6). Pod yield during the year was significantly (P < 0.05) higher in chlorpyrifos treatments and plots treated at pegging with 10.5 or 21.0 kg/ha NKWE, or at either planting or pegging with 21.0 kg/ha NKP compared with control. In 2010, percentage scarified pods was significantly (P < 0.05) lower in chlorpyrifos treatments and plots treated at pegging with 10.5 kg/ha NKWE, at planting with 21.0 kg/ha

Table 5. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on severity of early and late leaf spots, and percentage defoliation (Bagurugu, 2009 and 2010)

Treatment	Rate (kg/h)	Timing	Early leaf spots		Late leaf spots		Defoliation (%)	
			2009	2010	2009	2010	2009	2010
NKWE	10.5	planting	3.6^{bcd}	5.1^{b}	4.8^{bcd}	6.2^{b}	63.8^{b}	62.5^{b}
		pegging	3.7^{abc}	4.8^{bc}	5.1^{ab}	5.8^{bc}	63.8^{b}	57.5^{bc}
	21.0	planting	3.5^{bcd}	3.9^{de}	4.7^{cd}	4.9^{d}	65.0^{b}	52.5^{cd}
		pegging	3.3^{cd}	4.3^{cde}	6.9^{bcd}	5.3^{cd}	65.0^{b}	53.8^{c}
NKP	10.5	planting	3.7^{abc}	4.7^{bc}	5.1^{ab}	5.5^{c}	60.0^{b}	56.3^{c}
		pegging	3.8^{ab}	4.6^{bc}	4.9^{bcd}	5.5^{c}	60.0^{bc}	55.0^{c}
	21.0	planting	3.7^{abc}	4.5^{bcd}	5.0^{abc}	5.3^{cd}	56.3^{c}	55.0^{c}
		pegging	3.7^{abc}	4.6^{bc}	4.9^{bcd}	5.5^{c}	60.0^{bc}	57.5^{bc}
Chlorpyrifos	2.0	pegging	3.2^{d}	3.8^{e}	4.6^{d}	4.8^{d}	56.3^{c}	47.5^{d}
Untreated		–	4.0^{a}	6.5^{a}	5.4^{a}	7.8^{a}	75.0^{a}	82.5^{a}
$P > F$		–	0.0114	< 0.0001	0.0085	< 0.0001	< 0.0001	< 0.0001
CV (%)			12.4	9.7	9.8	7.0	6.6	6.3

Leaf spot disease severity scores were rated on 10 plants using the Florida scale of 1–10 based on visual observations (Chiteka *et al.* 1997); means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at P < 0.05

Table 6. Effect of neem kernel water extract (NKWE) and neem kernel powder (NKP) soil treatment of peanut at planting or pegging on percentage scarified and bored pods and pod yield (Bagurugu, 2008–2010)

Treatment	Rate (kg/ha)	Timing	Scarified pods (%)			Bored pods (%)			Pod yield (kg/ha)		
			2008	2009	2010	2008	2009	2010	2008	2009	1010
NKWE	10.5	planting	2.3[b]	5.8[b]	4.8[ab]	2.0[b]	5.5[cd]	3.8[bc]	909.4[bc]	1440.6[cd]	1681.3
		pegging	1.3[bc]	5.3[b]	1.3[c]	2.8[b]	8.8[bc]	3.0[c]	1034.4[ab]	1484.4[bc]	1665.6
	21.0	planting	2.0[bc]	4.7[b]	3.3[bc]	3.3[b]	9.5[bc]	4.0[bc]	1106.3[a]	1416.7[cd]	1625.0
		pegging	2.3[b]	5.3[b]	4.3[abc]	1.8[b]	6.5[cd]	3.8[bc]	1121.9[a]	1509.4[bc]	1503.1
NKP	10.5	planting	2.8[ab]	5.3[b]	3.8[bc]	3.3[b]	12.0[b]	5.8[b]	1006.3[ab]	1441.8[cd]	1656.3
		pegging	1.8[bc]	3.3[b]	4.3[abc]	4.0[b]	9.3[bc]	5.8[b]	1078.1[ab]	1465.8[cd]	1412.5
	21.0	planting	2.0[bc]	4.5[b]	4.5[ab]	3.3[b]	8.5[bc]	5.0[bc]	1147.2[a]	1595.8[b]	1615.6
		pegging	2.5[b]	2.8[b]	3.3[bc]	1.8[b]	8.8[bc]	3.3[c]	1121.9[a]	1518.8[bc]	1543.3
Chlorpyrifos	2.0	pegging	0.5[c]	0.8[b]	1.8[bc]	1.5[b]	2.3[d]	0.3[d]	1053.1[ab]	1884.4[a]	1806.3
Untreated	-	–	5.0[a]	13.8[a]	7.3[a]	10.0[a]	18.8[a]	9.8[a]	768.8[c]	1356.3[d]	1354.7
P > *F*		–	0.0080	0.0039	0.0394	0.0111	< 0.0011	< 0.0001	0.0083	< 0.0001	0.0718
CV (%)			25.6	68.3	56.5	33.5	33.4	38.3	12.5	15.1	11.9

Means within a column followed by the same letters are not significantly different according to Fisher's Protected *LSD* test at $P < 0.05$

NKWE or 10.5 kg/ha NKP, or at pegging with 21.0 kg/ha NKP compared with control. Percentage bored pods during the year was also significantly ($P < 0.05$) lower in chlorpyrifos and *A. indica* treatments than control. There were, however, no significant differences ($P > 0.05$) detected in pod yield among the treatments (Table 6).

DISCUSSION

Peanut pest management relies heavily on chemical-based crop protection strategies. However, chemical control is very expensive and not sustainable for farmers in developing countries like Ghana. Extracts from *A. indica* that is indigenous to Ghana and occurs abundantly in the wild have shown pesticidal effects that could be exploited for control of pests and diseases in peanut. In addition to being a cheaper source of biopesticide, the extracts are also thought to be less detrimental to the environment compared to synthetic pesticides (Isman 2006). Although peanut farmers in Ghana appreciate the yield-limiting effects of attack by soil arthropod pests and leaf spot diseases, they seldom apply protection for their crops due largely to financial limitations for chemical protection that is recommended for control (Abudulai *et al.* 2009). It was against this background that this study was conducted to evaluate the efficacy of neem kernel water extract and powder for managing damage by soil arthropod pests and leaf spot diseases to boost peanut yield in Ghana.

Results from the study showed that both the NKWE and NSP tested were efficacious against the soil arthropod pests and leaf spot diseases attacking peanut in Ghana. At Nyankpala, *A. indica* products at the concentrations tested showed efficacy comparable to chlorpyrifos in lowering populations of millipedes, white grubs, and termites in 2008 and millipedes in 2009. Populations of millipedes and white grubs were also lowered by the *A. indica* treatments at Bagurugu in 2008 and 2010, respectively. In a soil dip bioassay, Ranger *et al.* (2009) reported that the neem-based product, Azatin, exhibited high toxicity to the white grub larvae *Popillia japonica* Newsman, *Rhizotrogus majalis* (Razoumowsky), and *Anomala orientalis* Waterhouse. Also, Cherry and Nuessly (2010) reported that azadirachtin treated soil was repellent to wireworms and lowered their populations than untreated controls. Furthermore, Umoetok *et al.* (2009) reported that soil treatment with neem seed powder and extract lowered populations of the flea beetle *Ootheca mutabilis* (Shalberg) on fluted pumpkin, *Telfaria occidentalis* (Hoof L.) in Nigeria. Javed *et al.* (2008) also reported that soil application of crude neem formulations significantly reduced the invasion of tomato roots by root-knot nematodes. In the present study, early and late leaf spot severity and percentage defoliation were also generally lowered by the NKWE and NKP treatments. This is consistent with the report that *A. indica* treatment inhibited spore germination and mycelial growth of fungal leaf disease (Kale & Holey 1994; Bambawale *et al.* 1995; Gahukar 2000).

Percentages of scarified and bored pods were always lower in chlorpyrifos and *A. indica* treatments, with the exception of the results for 2009 at Nyankpala. The lower damage resulted in increased yield at Nyankpala in 2008 and at Bagurugu in 2008 and 2009. Data from this study are in agreement with those of Umoetok *et al.* (2009). They reported that soil treatment of *A. indica* products significantly lowered damage to fluted pumpkin leaves by *O. mutabilis* and resulted in increased yield over untreated control. Although, all the *A. indica* treatments in the present study were generally effective at the concentrations tested, the higher concentrations showed more efficacy in lowering damage and improving yield. Pod damage and yield from plots treated with the lower concentration of 10.5 kg/ha NKWE especially at planting was usually not different from untreated control. Several workers have reported that the activity of *A. indica* was concentration dependent (Schmutterer 1990; Abudulai *et al.* 2003). For control of leaf spots, however, the lower concentrations of 10.5 kg/ha NKWE effectively lowered severity of the disease especially when applied at planting.

In conclusion, the study demonstrated the effectiveness of *A. indica* products for lowering damage by soil arthropods and leaf spot diseases for increased peanut yield in Ghana. The results also confirmed the systemic effect of *A. indica* treatments reported by Thoeming and Poehling (2006) and Thoeming *et al.* (2006). These findings are important for farmers in Ghana who could now exploit the potential of *A. indica* for control of pests in their peanut fields with possible extension of the technology to other crops.

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Received for publication June 4, 2012
Accepted after corrections November 5, 2012

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