Survey and Management of Soil Arthropods in Peanut (*Arachis hypogaea* L.) in Southern Ghana, West Africa

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ABSTRACT

Peanut (*Arachis hypogaea* L.) is an important food and cash crop in Ghana, West Africa. Soil arthropods often cause kernel and pod damage that can lower yield. A survey of peanut fields was conducted with farmers in Ashanti, Brong Ahafo, Eastern, and Volta regions of Ghana, West Africa during 1999 and 2001 to identify soil arthropods and quantify damage to pods and kernels from arthropods. Soil arthropod pests observed in peanut fields during both years across all regions were white grubs (Coleoptera: Scarabeidae), millipedes (Myriapoda: Diplopoda), symphilids (Myriapoda: Symphyla), termites (Isoptera: Termitidae), earwigs (Dermaptera: Forficulidae), wireworms (Coleoptera: Elateridae), red ants (Hymenoptera: Formicidae), and mealybugs (Homoptera: Pseudoccoccidae). Black ants (Hymenoptera: Formicidae) and centipedes (Myriapoda: Chilopoda) were predatory arthropods found in these fields. Termite was the predominant arthropod in all regions. Black ants were the predominant predatory arthropod. Although percentages of unfilled pods were high in all the regions during both years, damage caused by soil arthropods was relatively low. In experiments conducted during 2003 (Kwadaso) and during 2004 (Ejura) peanut damage and yield were compared when the cultivars Konkoma and ICG FDRS-20 × F-MIX-38 were treated with carbofuran or chlorpyrifos. Low populations of soil arthropods were observed at both Kwadaso and Ejura regardless of insecticide treatment. Chlorpyrifos was more effective than carbofuran in maintaining yield. A single application of chlorpyrifos applied at planting was as effective as a single application at planting followed by a second application 60 days after planting. Yield of ICG FDRS-20 × F-MIX-38 was generally higher than the local cultivar Konkoma regardless of insecticide treatment.

Key Words: Carbofuran, chlorpyrifos, insect damage, integrated pest management.

Peanut (*Arachis hypogea* L.) is one of the main cash crops in Ghana, West Africa and is grown primarily by resource-poor, smallholder farmers. Confectionary nuts make up the bulk of production and consumption in Ghana, similar to their use in Zambia (Sandhu *et al.*, 1986). Peanut productivity in West Africa is limited by a number of biotic and abiotic constraints including soil arthropods, foliar and soil borne diseases, peanut rosette virus (*Peanut rosette umbravirus*), aflatoxin (*Aspergilus flavus*) contamination, interference from weeds, and drought (Bowen and Mack, 1993; Johnson and Gumel, 1981; Johnson *et al.*, 1981; Lynch *et al.*, 1989; Lynch and Douce, 1992; Wightman and Ranga Rao, 1993; Wightman and Wightman, 1994; Wightman *et al.*, 1990; Umeh *et al.*, 2001).

Arthropods infesting peanut and consistently reducing yield in sub-Saharan Africa include termites, white grubs, millipedes, and nematodes (Rhabditida: Steinermatidae and Heterorhabditidae) (Feakin, 1973; Johnson *et al.*, 1981; Raheja, 1975; Sohati and Sithanathan, 1990; Tsigbey *et al.*, 2003). Other pests such as wireworms (Elateridae), doryline ants (Hymenoptera: Formicidae), earwigs (Dermaptera: Forficulidae), and false wireworms (Tenebrionidae) are reported to be occasionally damaging in peanut (Wightman and Ranga Rao, 1993). Termites include *Macrotermes* spp., *Odontotermes* spp. and *Microtermes* spp. The above pests damage peanut pods and seeds. White grubs, symphilids (Myriapoda: Symphyla), termites, and wireworms destroy the roots, while termites cause pod scarification and eat the haulm (Wightman *et al.*, 1990; Wightman and Ranga Rao, 1993). Johnson *et al.* (1981) reported a yield loss of 40% caused by *Microtermes* spp. to peanut in Nigeria. Damage to the pods can also result in invasion of the seeds by soil fungi. Infection by fungi can lead to reduction in quality, caused by internal decay, deterioration of the seed and the production of mycotoxins, especially aflatoxins (Johnson and Gumel, 1981; Martin and Gilman; 1976; McDonald, 1970; Lynch *et al.*, 1989; Perry, 1967; Porter *et al.*, 1972; Wilson, 1945).

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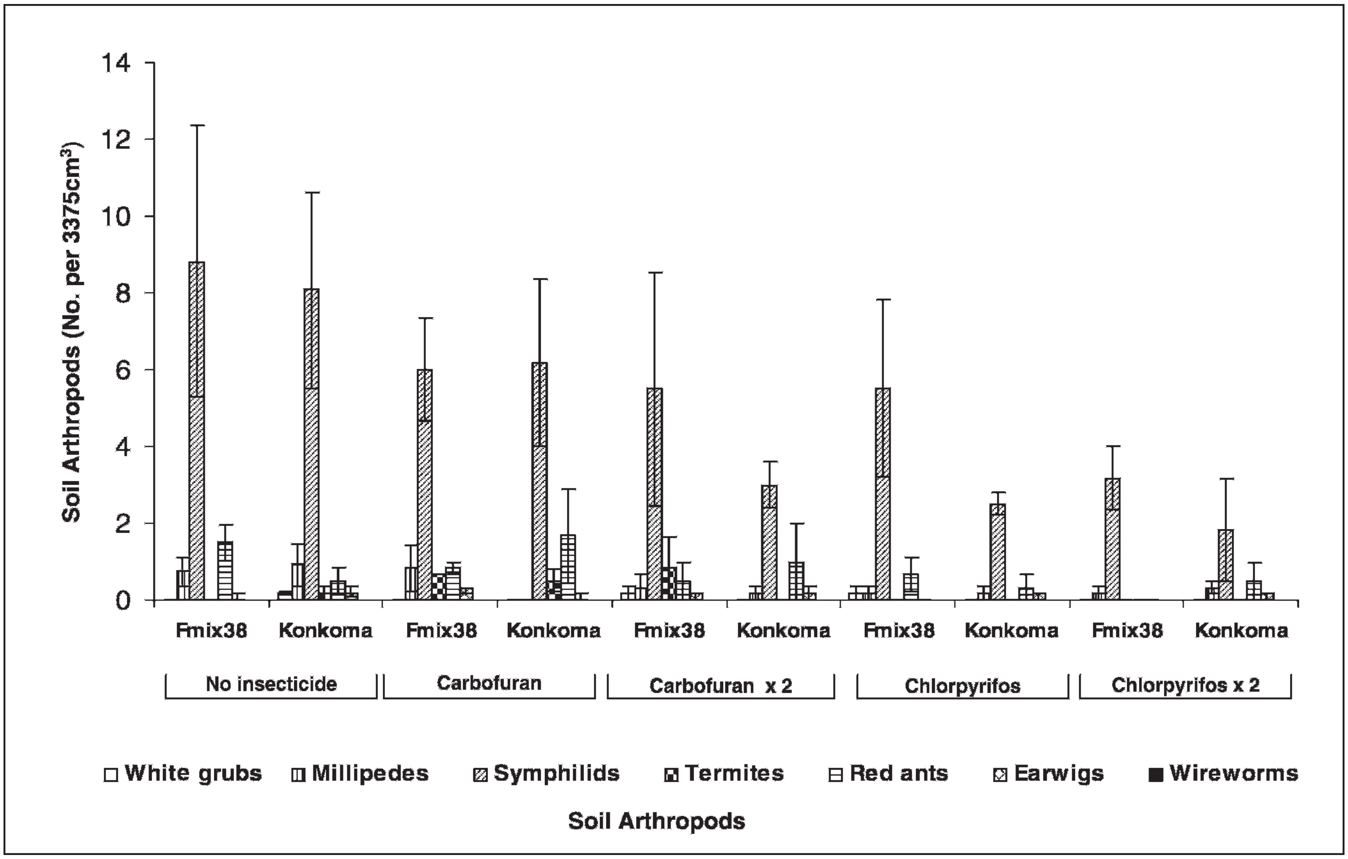

Fig. 1. Mean number of soil arthropod pests at harvest of peanut treated with insecticides at Kwadaso during the 2003 major season.

Rosette and Cercospora leaf spot (*Cercospora arachidicola* and *Cercospora personatum*) and interference from weeds are major limitations to optimum peanut production in Ghana. Cultural practices including improper application of manure, leaving crop residues on farms, delaying planting and harvesting, and abiotic factors such as rainfall and soil texture also influence soil pest occurrence and damage. Despite pest concerns, peanut farmers in most areas of sub-Saharan Africa seldom apply effective control measures against soil pests (Johnson *et al.*, 1981).

Research indicates that carbofuran and chlorpyrifos control a wide range of soil arthropods without damaging peanut (Wightman *et al.*, 1990; Wightman and Ranga Rao, 1993). Numerous studies have documented yield increases following application of insecticides in peanut in Africa (Wightman *et al.*, 1990; Wightman and Ranga Rao, 1993). Although synthetic insecticides are used routinely in production systems for peanut in developed countries, they are not routinely applied in countries like Ghana where the availability of commercial products is limited and financial constraints prevent purchasing these materials. However, the cost effectiveness of synthetic insecticides has not been adequately addressed in Ghana for peanut and empirical data on the actual losses caused by soil arthropods are limited in Ghana. The objectives of this study were to identify soil arthropods associated with peanut production in southern Ghana, to quantify yield loss due to these pests, and to determine the interaction of application timing of insecticides and cultivar in order to develop strategies for more effective peanut production in West Africa.

Materials and Methods

Survey of farmer fields for soil arthropods. Fields in the peanut production districts of Ashanti, Brong Ahafo, Eastern, and Volta regions in Ghana were visited during the major growing seasons during 1999 and 2001. Ten (1999) and eight (2001) villages in each region were visited and two fields per village were sampled (Table 1). The percentage of each cultivar grown in that area was determined. In each field, a 5 m × 5 m section was marked and five plants were randomly selected from two, 5 m by 5 m sections selected at random to assess presence of insect-feeding holes on pods and seeds. Sampling during 1999 occurred in late July in Ashanti and Brong Ahafo regions and in late August in Eastern and Volta regions. During 2001, fields were sampled in late August in Ashanti and Grong Ahafo regions and in mid-September in Eastern and Volta regions. Additionally, within each section five soil cores (15 cm^3) were removed to quantify soil arthropods. The percentage of unfilled pods was also determined from the five plants sampled.

Arthropod density was transformed to log^{10} prior to statistical analysis (Sokal and Rohlf, 1981). Data for counts of each arthropod, percentage unfilled pods, and damaged pods and kernels were analyzed using a general linear model procedure (SAS Institute, 1999–2000). When ANOVAs (analysis of variance) were significant ($P \leq 0.05$) treatment means were compared against control by Tukey's (HSD) test.

Efficacy of carbofuran and chlorpyrifos against soil arthropods. Experiments were conducted at Kwadaso, Kumasi (Lat, 6° 42 N; Long, 1° 40 W; 262 m above sea level) and at Hiawoannwu/Ejura (Lat, 7° 40 N; Long, 1° 39 W; 221.9 m above sea level) in the Ashanti region of Ghana to determine the effect of soil pesticides for arthropod control and peanut yield. Seedbeds were prepared by hand tillage and peanut was seeded in rows spaced 50 cm apart (Kwadaso) and 15 cm apart (Ejura). Plot length was 6 m and consisted of eight rows. Air temperature ranged from 29–32 C and 31–34 C with relative humidity of 70–80% and 50–65% for Kwadaso and Ejura, respectively. One improved peanut cultivar, ICG FDRS-20 × F-MIX-38 and a local cultivar, Konkoma, were planted in these experiments. Chlorpyrifos (Dursban 4E, Dow AgroSciences, Indianapolis, IN) was applied at planting as side dressing at 0.68 kg ai/ha. Similarly, carbofuran (Furadan 3G, FMC Corp., Philadelphia, PA) was applied in furrows at 1.0 kg ai/ha. The side dressing application was done in shallow furrows 20 mm deep and 0.10 m from the plant row. The furrows were covered with soil after application. A non-treated control for each cultivar was included. Treatments consisted of carbofuran or chlorpyrifos applied at planting or at planting followed by a repeat application 60 days after planting (DAP) at the same rate. Peanut was planted at Kwadaso on June 3, 2003 and on May 21, 2004 at Hiawoannwu and Ejura.

The experimental design was a randomized complete block with a 2 × 2 × 2 factorial treatment arrangement with three replications. The day before harvest, soil from a 15 cm × 15 cm × 15 cm section each was removed from two spots in each plot to determine arthropod density for each species. Damaged pods and kernels from two peanut plants removed from each plot were recorded. Pod weight from plants within one m of the two middle rows of each plot was recorded.

Table 1. Percent of peanuts for each cultivar in four regions of southern Ghana during 1999 and 2001.

Region	Cultivar	Percentage of cultivar	
		1999	2001
Ashanti	China	20	70
Ashanti	Broni	33	20
Ashanti	Konkoma	40	10
Ashanti	Kowoka	7	0
Brong Ahafo	China	42	30
Brong Ahafo	Afromo	17	36
Brong Ahafo	Konkoma	8	18
Brong Ahafo	Bremawuo	33	16
Eastern	Cameroun	71	50
Eastern	Konkoma	29	50
Volta	Konkoma	0	37
Volta	Kpedevi (Obaatan)	44	24
Volta	Kpanlogo	0	13
Volta	Kluklukluі	6	13
Volta	Cameroun	44	13
Volta	Goroga (Akukorku)	6	0

Data for total arthropod density, density of each arthropod group, damaged pods, damaged kernels, unfilled pods, and pod yield were subjected to analyses of variance (SAS Institute, 1999–2000). Means were separated using Tukey's (HSD) test at $p \leq 0.05$. Arthropod density was transformed (log_{10}) before analyses (Sokal and Rohlf, 1981).

Results and Discussion

Survey of farmer fields for soil arthropods. The peanut cultivar Konkoma was planted in all regions during 2001 and in three regions during 1999 (Table 1). Although the percentage of Konkoma decreased from 1999 to 2001 in Ashanti region, the percentage of this cultivar increased in Brong Ahafo, Eastern, and Volta regions. Konkoma was cultivated across the regions because it has been a standard cultivar for decades.

Soil arthropod pests observed in all the regions during both years included white grubs, millipedes, symphilids, termites, red ants, earwigs, wireworms, and mealybugs while predators included black ants and centipedes (Tables 2 and 3). Most of these damage-causing organisms have been previously reported by other researchers in peanut fields (Bowen and Mack, 1993; Feakin, 1973; Johnson *et al.*, 1981; Lynch and Douce, 1992; Raheja, 1975; Sohati and Sithanatham, 1990; Tsigbey *et al.*, 2003; Wightman *et al.*, 1990; Wightman and Ranga Rao, 1993; Wightman and Wightman, 1994; Umeh *et al.*, 2001). Termites were observed in all the regions

Table 2. Mean numbers of arthropod pests and predatory arthropods from farmers' fields in four regions of southern Ghana during the 1999 major season.[a]

Region	Arthropod pests								Predatory arthropods	
	White grubs	Millipedes	Symphilids	Termites	Red ants	Earwigs	Wireworm	Mealybugs	Centipede	Black ants
	No./15 cm^3									
Ashanti	0.16 a	0.28 ab	0.50 b	7.38 a	3.13 a	0.02 a	0.06 a	0.00 b	0.10 c	4.33 a
Brong Ahafo	0.26 a	0.46 a	2.66 a	6.28 a	14.70 a	0.07 a	0.09 a	0.02 b	0.42 a	1.60 a
Eastern	0.08 a	0.30 ab	1.49 b	8.36 a	2.81 a	0.01 a	0.03 a	0.61 ab	0.26 b	4.95 a
Volta	0.20 a	0.16 b	1.08 b	2.43 a	4.62 a	0.08 a	0.07 a	1.14 a	0.23 b	2.94 a
F Value	0.9	3.57	6.64	1.61	2.65	2.68	1.12	3.42	8.59	0.35
P > F	0.4422	0.139	0.0002	0.1852	0.048	0.0462	0.3394	0.017	<0.0001	0.7858

[a]Means for individual arthropods followed by the same letter are not significantly different according to Tukey's (HSD) test at $p \leq 0.05$.

during 1999 and 2001 (Tables 3 and 4). Although red ants were not present in 2001, they were present during 1999, and higher populations were noted in particular in the Brong Ahafo region (Tables 3 and 4). Symphilids were present during both years but at lower populations than termites or red ants in 1999 or termites in 2001 (Tables 2 and 3). Populations of centipedes were low compared to those of black ants. Low numbers of some of the arthropods may be attributable to the high populations of the predatory black ants (Table 3 and 4), which may suppress the populations of other arthropods. Sekamatte *et al.* (2000) and Erbaugh *et al.* (2003) also indicated that an increase in ant population and activity, through baiting, significantly reduced termite damage in corn (*Zea mays* L.).

The percentage of unfilled pods during 1999 and 2001 ranged from 41 to 62% (Tables 4 and 5). Percentages of insect-damaged pods and kernels were relatively low across all regions during both years. Damage may have resulted from low calcium in soil solution and the inconsistent maturity of the crop. Calcium is critical for adequate pod development and optimum yield (Barber, 1984; Smal *et al.*, 1989; Summer *et al.*, 1988). Nevertheless, the feeding holes of these arthropods could constitute routes of infection by aflatoxin-producing fungi, contaminating and reducing quality of kernels (Bowen and Mack, 1993; McDonald and Harkness, 1963).

Efficacy of carbofuran and chlorpyrifos against soil arthropods. Populations of white grubs, millipedes, termites, red ants, earwigs, and wireworms were relatively low and few differences were noted when comparing among insecticide treatments during 2003 at Kwadaso (Figure 1). High populations of symphilids were noted, and chlorpyrifos usually demonstrated a trend to reduce populations of this soil arthropod. Carbofuran was generally less effective than chlorpyrifos and while trends were consistent, significant differences among treatments were not common. There was no advantage to applying chlorpyrifos both at planting and 60 days after planting compared with a single application at planting (Figure 1). During 2004 at Ejura, no differences in populations of white grubs, millipedes, symphilids, termites, earwigs, and wireworms were noted (data not presented). Although relatively high populations of termites were noted at this location, no treatment

Table 3. Mean numbers of arthropod pests and predatory arthropods from farmers' fields in four regions of southern during the 2001 major season.[a]

Region	Arthropod pests								Predatory arthropods	
	White grubs	Millipedes	Symphilids	Termites	Red ants	Earwigs	Wireworms	Mealybug	Centipedes	Black ants
	No./15 cm^3									
Ashanti	0.03 b	0.20 a	0.70 ab	10.89 a	0.14 a	0.20 ab	0.07 a	0.00 a	0.34 a	3.53 a
Brong Ahafo	0.19 a	0.37 a	1.17 a	9.83 a	0.92 a	0.06 b	0.03 ab	0.12 a	0.22 a	5.77 a
Eastern	0.05 ab	0.24 a	0.75 ab	4.41 a	0.31 a	0.32 a	0.00 b	0.05 a	0.43 a	2.57 a
Volta	0.10 ab	0.13 a	0.50 b	5.92 a	0.54 a	0.123 b	0.03 ab	0.02 a	0.18 a	2.28 a
F Value	2.87	2.93	3.84	0.83	1.01	5.98	1.85	1.35	2.84	1.65
P > F	0.0361	0.0337	0.0098	0.4761	0.3896	0.0005	0.1383	0.2593	0.038	0.1767

[a]Means for individual arthropods followed by the same letter are not significantly different according to Tukey's (HSD) test at $p \leq 0.05$.

Table 4. Percentage unfilled pods, damaged pods, and damaged seeds of peanut from farmers' fields in four regions of southern Ghana during the 1999 major season.[a]

Location	Unfilled pods	Damaged pods	Damaged seed
	%		
Ashanti	45 a	4 a	7 a
Brong Ahafo	41 b	3 ab	7 a
Eastern	51 a	3 ab	4 ab
Volta	50 a	1 b	3 b
F Value	6.8	3.66	3.85
P > F	0.0002	0.0123	0.0093

[a]Means for each parameter followed by the same letter are not significantly different according to Tukey's (HSD) test at $p \leq 0.05$.

differences were observed when comparing non-treated peanut with either insecticide treatment (data not presented).

Populations of centipedes, a predatory arthropod, were low regardless of whether or not insecticide was applied at Kwadaso (Figure 2) and Ejura (data not presented). In contrast, high populations of black ants were noted for some but not all treatments. Surprisingly, the highest population was noted when carbofuran was applied at planting to the cultivar Konkoma. Black ant population was consistently low when chlorpyrifos was applied at planting only or when applied at planting and repeated 60 days after planting. Although considerable variation was noted for black ant populations at Ejura during 2004, fewer black ants were associated with the cultivar Konkoma (Figure 3).

The percentage of unfilled pods ranged from 7 to 25% at Kwadaso during 2003 (Figure 4). Generally, a higher percentage of unfilled pods was noted for the cultivar Konkoma compared with FDRS-20 × F-MIX-38. However, no differences in the percentage of unfilled pods were noted when comparing insecticide treatments within a cultivar. Damage to pods and kernels from arthropods was less than 5% and no differences among insecticide treatments and cultivars were noted (Figure 4). A similar trend was noted at Ejura during 2004 where considerable variation in the percentage of unfilled pods was noted and few differences in percentages of damaged pods and kernels were noted (Figure 5). Limited pod fill is often associated with low calcium levels in soil (Barber, 1984, Summer *et al*., 1988 and Smal *et al*., 1989) and this was the case at both locations (S. Osei-Yeboah *et al*., unpublished data). These data also indicate that FDRS-20 × F-MIX-38 may be better suited for the region, at least with respect to pod fill. Additionally research comparing cultivar response to calcium is needed to determine the cause of differences noted in these experiments. Peanut was harvested at optimum maturity for each cultivar.

Table 5. Percentage unfilled pods, damaged pods, and damaged seeds of peanut from farmers' fields in four regions of Ghana, major season, 2001.[a]

Region	Unfilled pods	Damaged pods	Damaged seed
	%		
Ashanti	39 c	3 a	3 a
Brong Ahafo	40 c	3 a	4 a
Eastern	62 a	4 a	4 a
Volta	62 a	3 a	4 a
F Value	19.32	0.27	0.43
P > F	<.0001	0.8454	0.7281

[a]Means for individual arthropods followed by the same letter are not significantly different according to Tukey's (HSD) test at $p \leq 0.05$.

Pod yield was not affected by cultivar or insecticide treatment at Kwadaso during 2003 (Figure 4). Applying chlorpyrifos either at planting only or at planting followed by application 60 days after planting produced a trend for higher yield compared with non-treated peanut and peanut treated with carbofuran at Ejura in 2004. Yield of FDRS-20 × F-MIX-38 with one or two applications of chlorpyrifos was higher yield than the non-treated control or carbofuran treated FDRS-20 × F-MIX-38. When Konkoma was treated with chlorpyrifos in a similar fashion, yield was higher than yield of Konkoma treated with carbofuran or when Konkoma was not treated with insecticide. The yield increase associated with application of chlopyrifos did not appear to be associated with insect populations and subsequent damage to pods and kernels. However, chlorpyrifos has been shown to reduce incidence of southern stem rot (caused by *Sclerotium rolfsii* Sacc.) (Melouk et al., 1995).

Collectively, results from this survey indicate that a wide range of soil arthropods are present in fields associated with peanut production in southern Ghana. Despite low arthropod pest damage to pods, yield increased when chlorpyrifos was applied in one (Ejura) of the two locations but not when carbofuran was applied. This may be due to non-insecticidal effects including suppression of disease. While soil arthropods did not appear to play a significant role in yield reductions in the two locations evaluated in this study, the wide array of species and consistent occurrence would indicate that under certain environmental conditions, one or more species might reach significant pest status. This would be particularly true under hot and dry

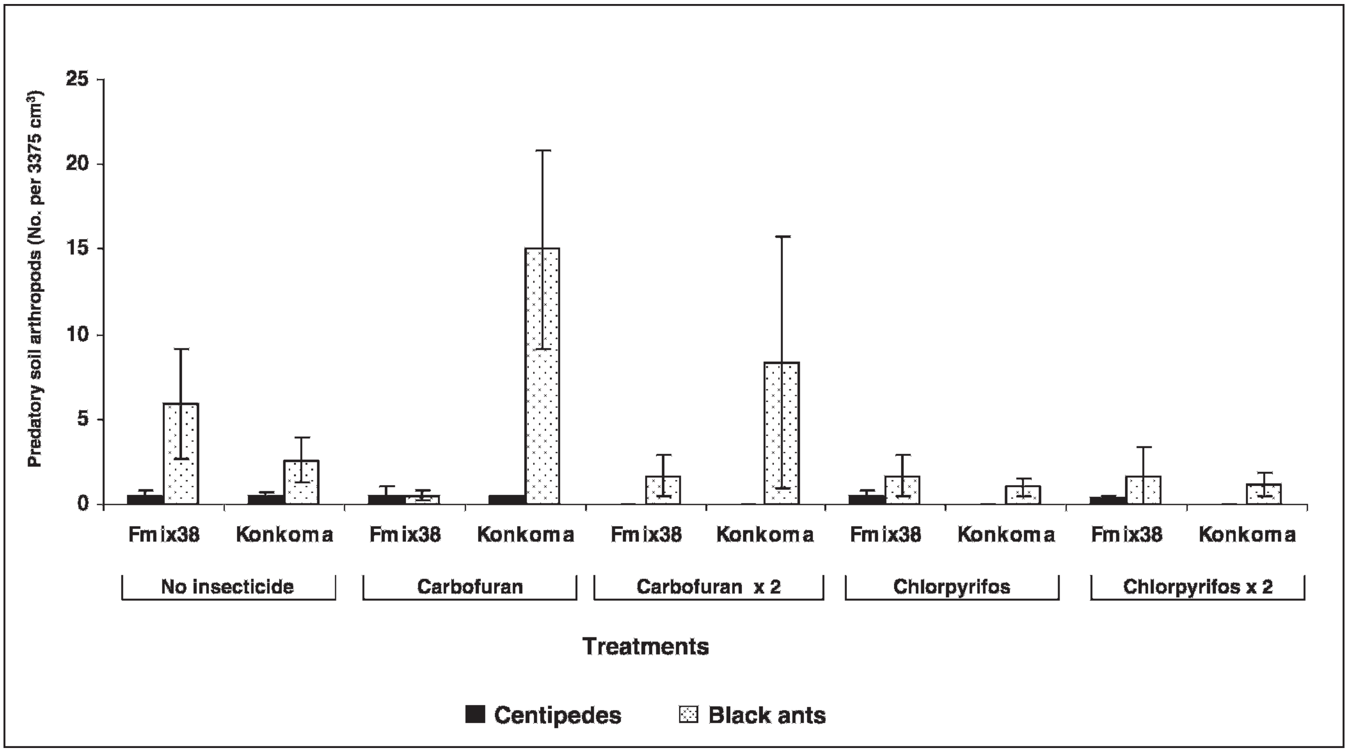

Fig. 2. Mean number of predatory arthropods at harvest of peanut treated with insecticides at Kwadaso during the 2003 major season.

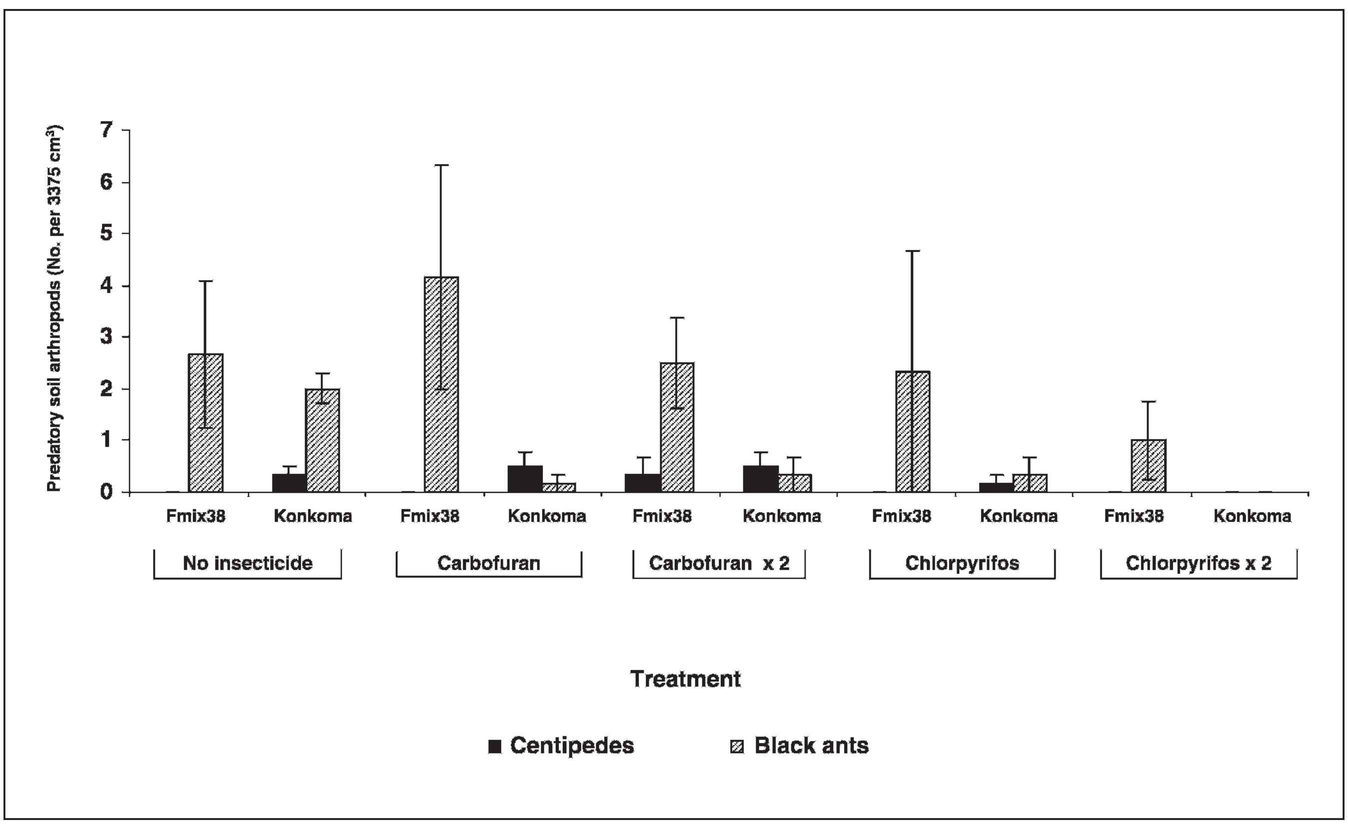

Fig. 3. Mean number of predatory arthropods at harvest of peanut treated with soil pesticides at Ejura during the 2004 major season.

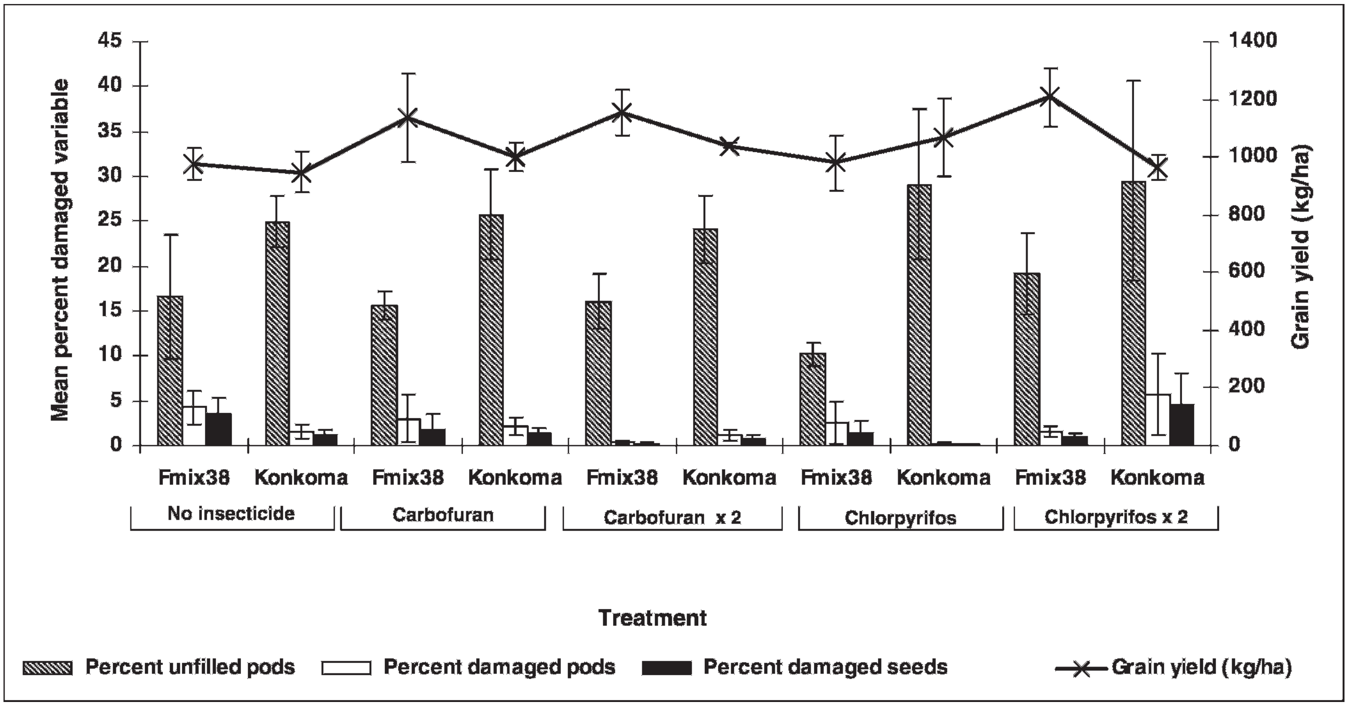

Fig. 4. Grain yield and percentage of peanut pods and seeds damaged by soil pests at harvest of peanut treated with soil pesticides at Kwadaso during the 2003 major season.

conditions for termites. Additional research is needed to compare peanut response to insecticides and document the role of these products in suppressing pests other than arthropods. Defining relationships among pest management practices and other agronomic inputs related to cultivar is needed to develop comprehensive production systems for peanut production in southern Ghana.

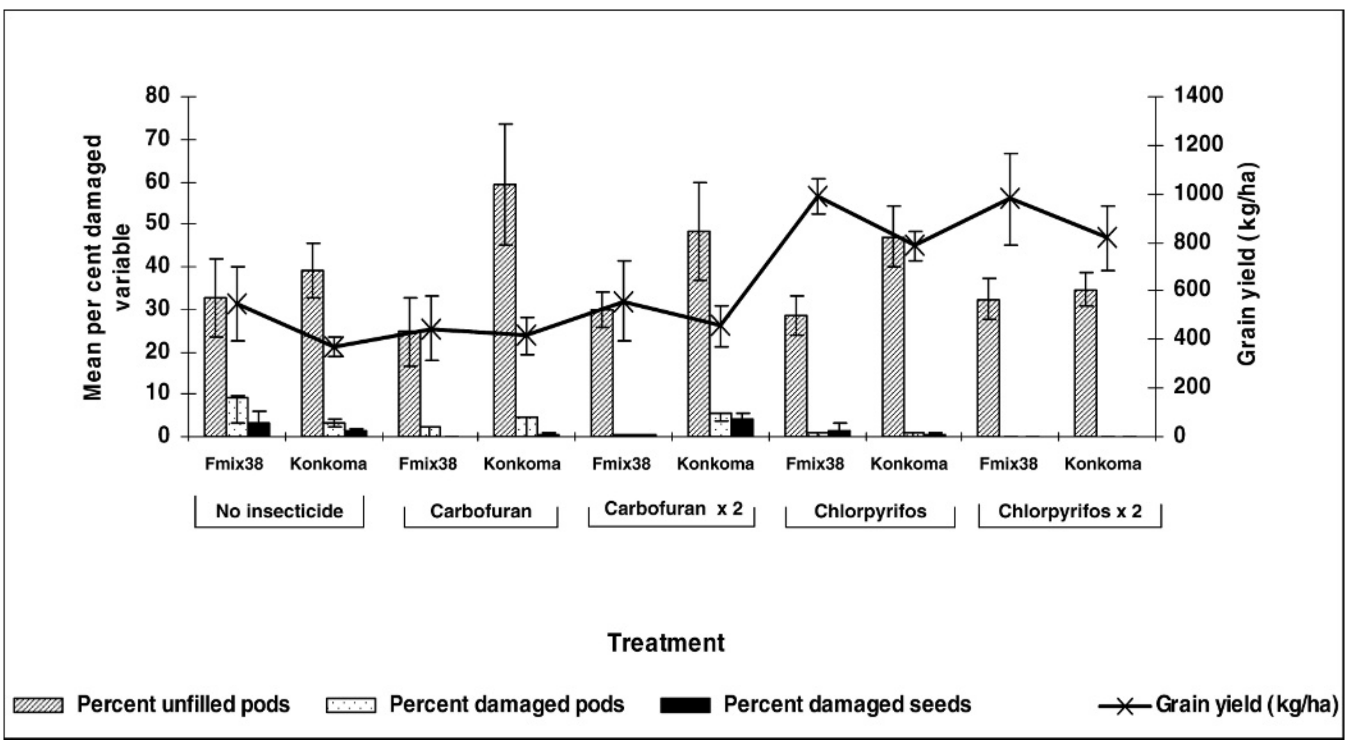

Fig. 5. Grain yield and percentage of peanut pods and seeds damaged by soil pests at harvest of peanut treated with soil pesticides at Ejura during the 2004 major season.

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