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Effects of groundnut genotypes, cropping systems and insecticides on the abundance of native arthropod predators from Uganda and Democratic Republic of Congo

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Abstract

Knowledge of the distribution, abundance, species diversity and effectiveness of indigenous natural enemies of groundnut pests in Uganda and the Democratic Republic of the Congo (DRC) is poor. Similarly, effects of insecticides commonly used by groundnut producers on arthropod predators are not documented in these countries; so effects of insecticides on these natural enemies were monitored in field trials with groundnut grown solely and in association with maize in eastern Uganda and in eastern DRC, during long and short rains of 2002 and 2003 to monitor the abundance of arthropod predators under various groundnut cropping systems. Groundnut genotypes were grown sole or in association with maize. Crops were planted in split-plot designs. Treatments were associated with three levels of insecticide application. Abundance and distribution of predators such as coccinellidae, syrphidae, anthocoridae, carabidae, mantodea, staphylinidae, and chrysopidae were observed to be significantly ($P<0.05$) affected by the groundnut cropping system, the rate of insecticide application and not by the groundnut genotypes. Groundnut genotypes had no effect on predators' abundance. The DRC site had a high number of predator species than the Uganda site. Insecticide applications reduced activities of predators at more than 50% across seasons, study sites and cropping systems. Lower pests pressure on groundnut genotypes, higher abundance of predators and higher groundnut yields were observed to be associated with groundnut/maize cropping system. Therefore groundnut/maize should be promoted among other biological control conservation strategies, aiming at enhancing natural enemies in groundnut systems, through habitat manipulation of local environments. This study indicated that generalist predators, through their activities may be important natural enemies of groundnut pests in Uganda and in DRC.

Key words: Predators, groundnut genotypes, cropping systems, insecticide, Uganda, Democratic Republic of the Congo, biological control conservation and enhancement.

Introduction

Groundnut (*Arachis hypogaea* L.) is the second most widely grown grain legume in Democratic Republic of the Congo (DRC) (Munyuli, 2003) and in Uganda (Mukankusi *et al*., 1999) after beans (*Phaseolus vulgaris* L.). Yields (unshelled nuts) of up to 3.5 t/ha have been reported from countries with developed agriculture (Subrahmanyam *et al*., 1999; Mack *et al*.,1987) but only 0.2 to 0.8 t/ha are normally recorded at farmer level in Sub-Sahara Africa including Uganda (Mukankusi *et al*., 1999) and DRC. The low yields at the farmer level are attributed to a number of abiotic and biotic factors (Frazer and Gilbert, 1976) but heavy biotic pressure from insect pests is particularly important.

Pests of economic importance in tropical regions and in eastern Uganda and DRC are aphids (*Aphis craccivora* Koch; Homoptera Aphidae), thrips [*Frankliniella schultzei* (Trybom); Thysanoptera Thripidae] and leafminer [*Aproaerema modicella* (Deventer); Lepidoptera Gelechiidae], (Shanower and Rao, 1999; Kamala and Padmavathamma, 1996; Mukankusi *et al*., 1999).

The main tactic for controlling these pests has been chemical pesticides. However, these pesticides have negative effects on the environment. There is a great challenge of finding out sustainable management tactics for groundnut in Uganda and DRC. Thus, it is needed to investigate more environmentally friendly alternatives (Markham *et al*., 1997; Neuenschwander *et al*., 2003).

Consequently, integrated pest management (IPM) is being promoted in eastern and central Africa as an alternative method to minimize pesticide use and encourage environmentally safe pest control tactics.

A key component of IPM is biological control or it is often recommended as the first line of defence in IPM programs (Lugajo, 2001; Munyuli *et al*., 2006). Arthropod predators of groundnut pests are not documented in eastern Uganda and in DRC. The effects of insecticides application on them remain largely unknown.

With the limited information on the overall diversity, abundance and effectiveness of biological control agents, particularly with regards to the various cropping systems in which groundnut is planted., this study aimed: (1) to assess the impact of insecticides on groundnut yield, population density of arthropod predators and pests of economic importance, and (2) to investigate predators species abundance in various cropping systems in eastern Uganda and in eastern DRC.

Materials and methods

This study was conducted in Uganda and DRC to compare effects, if any between the ecologies on predators of groundnut pests. Since in groundnut, some varieties can attract herbivore pests and their natural enemies more than others, therefore, improved and local varieties were also included as variables in order to test their potential effects.

In Uganda, the study was conducted at the Technology Verification Centre (TVC) in Bukkedea, Kumi District (33°7'E, 15°'N, 1116 m above sea level). Bukkedea area has on average a mean annual rainfall of 900 mm and 17.5/27.5 °C minimum/maximum temperatures.

In the DRC, trials were conducted at Mulungu Agricultural Research Center (28°1'23"E, 1°42'25"S; 1580 m altitude) of INERA (Institut National pour l'Etude et la Recherche Agronomiques), Kivu Province (Munyuli, 2003).

Mulungu area has a tropical humid climate with bimodal rainfall of 1700 – 2200 mm (Bultot, 1950), distributed with the long rains from September to March and the short rains from March to May, and an average daily minimum/maximum temperatures of 10/26 ºC with 71/76% relative humidity (Munyuli, 2003). Mulungu is located in a high mountainous zone and is bordered by mountain forests of Kahuzi Biega National Park on the west and Lake Kivu on the east. The trials were sown in a clay-sandy loam soil (Uganda) and in ferrosol (DRC).

Trials in Uganda were conducted during long rains (April, 5 to August, 29 of 2002 and 2003); and in DRC, during long rains (November 7, 2002 to March 5, 2003) and short rains (March 25 to June 25 of 2003). No trials were conducted during dry seasons since groundnut is not cultivated during that period.

A mixture of dimethoate (Roger 40EC) and cypermethrin is recommended for control of groundnut pests (E-pieru, personal communication), so the trials had three levels of insecticide spray:

i) Dose 1 = Untreated (= unsprayed);
ii) Dose 2 = 0.5 dose i.e. half the recommended dose (5 ml of cypermethrin + 12.5 ml of dimethoate in 10 litres of water);
iii) Full dose, i.e. the recommended dose (10ml of cypermethrin + 25ml of dimethoate in 10 litres of water). Around 0.6 liters of dimethoate and 0.20 liters of cypermethrin were used per ha sprayed.

Insecticide was applied using a knapsack sprayer fitted with a cone nozzle at two week intervals, starting at 2 weeks post emergence of the crops, up to crops maturity (90 days), over the whole period, 5 rounds of insecticide sprays were achieved.

Insecticide drift to neighbouring plots was restricted by having polyethylene sheets between plots while spraying between 0700 and 0900.

In Uganda, two genotypes were grown: Igola I (improved genotype) and Erudurudu (local genotype). In DRC, the corresponding genotypes grown included, GL24 (improved genotype) and Bunyakiri (local genotype). These local and improved genotypes are genetically the same but having different names in the two countries. The genotypes were grown sole or intercropped with a commercial variety of maize: Longer 5, in Uganda or Bambou in DRC.

Local genotypes differ from improved genotype on their socio-economic values and in their agro-morphological characteristics. Local materials are generally varieties already adapted to local environments, being in use by farmers since memorial time and very popular. Although relatively tolerant to pests and diseases, these local varieties are low yielding and late maturing. In Uganda as well as in DRC, there are several plants interested in processing cooking oil from groundnut seeds. These plants purchase groundnut seeds from rural areas. Therefore, several improved and high yielding and commercial varieties were introduced in rural areas of eastern DRC and eastern Uganda, by various stakeholders interested in improving livelihoods of farmers, to enable them increasing their income, through the promotion of cash varieties. In the region, farmers prefer to maintain local genotypes because they require less inputs and less care as compared to improve varieties that require a lot of inputs including insecticide sprays to get good yield. Additionally, in eastern DRC, a Kg of groundnut seed cost $ 1.5-3 (improved genotypes) against $ 0.5-1 (local genotypes). Therefore, in eastern DRC, farmers grow the two types of varieties for both their local consumption (local genotypes) and for their income increase through sale of improved variety seeds to plants interested. Most farmers maintain these improved varieties to respond to the demand in the local industrial sector specially.

The above mentioned groundnut varieties were selected in this study mainly for being popularly used by farmers, but also for ecological reasons: improved genotypes being high yielding but susceptible to pests and probably may attract high diversity of natural enemies of groundnut pests under local intercropping conditions. Since farmers seem to be obliged to continue cultivating improved genotypes to respond to local market demands, therefore, there is a need for researchers to find out farming practices that reduce groundnut producers' reliance on insecticides to get good yield. This is also important because not all farmers can afford to buy insecticides all the time, moreover insecticides pollute the environment.

The experimental design was split-plot with cropping systems as main plots (20 x 20 m) .genotypes as sub-plot and insecticides as sub-sub-plots, with four replicates.

The intercrops were grown in additive mixtures and the plant populations for both groundnut and intercrop components were based on a spacing of 45 x 15 cm, established as the optimum for groundnut in eastern U-ganda (Mukankusi *et al*., 1999) and in DRC (Mbikayi, personal communication).

The experimental plots were prepared using ox ploughs. The plots were hand weeded, at 2 and 5 weeks after seedling.

Data collection

Predators were counted *in situ*. Relative abundances of coccinellids larvae and adults, syrphid larvae, staphylinids larvae and adults, lacewings larvae and adults and mantids were assessed by randomly selecting 6 rows from each plot at the time of crop emergence.

Plants in these rows were inspected at 14 days intervals and predator population densities of coccinellids, staphylinids, mantids, etc., estimated by direct visual counts during their peak activity time (0900 to 1500) and thereafter left on the plants. In each plot, predators we counted for 20 min every hour during that peak activity time. Syrphid larvae were counted on flowers and groundnut shoots. *Orius* sp. (Hemiptera Anthocoridae) were counted on 50 flowers selected randomly from plants found in these six pre-randomly selected rows of each plot. Flowers were picked and placed in glass vials containing 70% ethanol solution, and taken to the laboratory. Subsequently, the flowers were dissected and washed to separate insects from plant parts, and predators counted.

Activities of earwigs, ground beetles, predatory mite, and spider predators were monitored using plastic pitfall traps (10 cm in diameter and 13 cm deep); container dug into the ground such that the upper edge of the container was flush with the ground surface. Sometimes, when it rained intensively, pitfall traps could over flow and we could record empty traps. Eighteen pitfall traps were arranged on 2 diagonal rows, across each plot at 3 m intervals as recommended by Agnew and Smith (1989). The trap rims were made level with the ground so as not to obstruct insect movement and the area around was kept bare to standardize the catching conditions. The traps were half-filled with an aqueous solution of 50% ethanol to preserve the insects, stop predation and increase retaining efficiency. The pitfall traps were emptied after 3 to 4 days and earwigs, ground beetle, predatory mite and spiders counted.

Population density fluctuations of groundnut pests (aphids, thrips and leafminer) of economic importance were monitored during the entire growing period of groundnut. Aphid numbers were estimated weekly by counting them on 10 groundnut plants selected randomly in each plot. On each plant, aphids' numbers were counted on all affected shoots and therefore, a mean for each plant was obtained. At the same moment, thrips density was estimated by counting the number of thrips on young shoots or flowers from 10 plants per plot and later on, values were calculated in terms of mean number of thrips per 5 shoots or 5 flowers. Leafminer population densities were estimated as numbers of pupae and larvae (all instars) per 50 mined leaves selected randomly on 10 plants also selected randomly per plot.

Yield of groundnut was assessed by harvesting (grains) in 1 m^2 in the middle of each plot, and later translated in tones/ha.

Data analysis

All data were subjected to analysis of variance (ANOVA), after checking the validity of the assumptions underlying this test. Predator population densities data were subjected to logarithmic (log10) transformation. Where the F-statistics indicated significant effects, means were separated using Fisher's protected least significant difference (LSD) test at 5% probability level. All analyses were done using Genstat computer package program (Gensat 5 release 3.2 PC/Windows 95).

Results

Several species were commonly observed. These include ladybirds, *Cheilomenes* sp. (Coleoptera Coccinellidae), syrphid larvae, *Syrphus* sp. (Diptera Syrphidae), spiders, *Lycosa pseudoannulata* (Boesenberg *et* Strand) (Aranaeae Lycosidae) and *Oxyopes* sp. (Aranaeae Agelenidae), earwigs, *Forficula auricularia* L. (Dermaptera Forficulidae), minute pirate bugs, *Orius* sp. (Hemiptera Anthocoridae) praying mantid *Mantis religiosa* (L.) (Dyctyoptera Mantidae), rover beetles, *Paederus* sp. (Coleoptera Staphylinidae), ground beetles, *Chlaenius* sp. (Coleoptera Carabidae), predatory mites (Acari Bdellidae) and lacewings, *Chrysoperla* sp. (Neuroptera Chrysopidae).

Unsprayed polycultures (groundnut/maize) supported significantly ($P<0.05$) higher numbers of arthropod predators than monocultures (tables 1 and 2). Seasonal variations in predator numbers were observed across all study sites. High abundances of predators were found in the DRC site than in the Ugandan one (tables 1 and 2). Mite predators were recorded in the DRC site only. In Uganda, ground beetles did not appear during 2002; but their activities were recorded during long rains of 2003. Higher numbers of predators were recorded in year 2003 than during 2002 in both study sites.

With minor exception from mantids, ladybirds, earwigs, ground beetle and staphylinid during 2003, the effect of genotypes on abundance of predators was not significant ($P>0.05$) in all study sites (tables 1 and 2). In some cases, predators were found to numerically occur in high numbers on local varieties than on improved ones (tables 1 and 2), and these differences were significant ($P<0.005$).

Insecticide sprays significantly ($P<0.05$) reduced numbers of predators (tables 1 and 2). Predator numbers were reduced at more than 50% of their total population when applying full dose than when applying 1/2 dose, (tables 1 and 2).

At two weeks after emergence of groundnut, all plots were already affected by aphids but their population remained significantly ($P<0.05$) higher in unsprayed than in sprayed plots (figures 1 and 2). At 4 and 8 weeks, more aphids were in the monoculture than in groundnut polycultures (figure 1). In all sprayed plots, aphid populations declined and were absent at 8 weeks. Herbivore pests (leafminer, thrips) pressure was lower on groundnut in groundnut/maize than in groundnut sole (tables 3 and 4). There was similar pressure of pests on all groundnut genotypes.

Across all seasons, unsprayed groundnut yields were significantly ($P<0.05$) lower than sprayed crops. Higher groundnut yields were observed for the two genotypes in unsprayed groundnut polyculture plots than in unsprayed groundnut monoculture (table 5). Groundnut yields in sprayed plots approximately reached expected yields under good management of the crop. Yields obtained under these trials reflected the situation the farmer face when the crop is not sprayed. There are several factors that influence the yield of groundnut crop including soil fertility level; however, in this study, the effect of not spraying on the low yields, is demonstrated.

Table 1. Effect of groundnut genotypes, cropping systems and insecticide sprays on the mean population density of predators in Kumi district, eastern Uganda.

a) Long rains, April-August, 2002

		Groundnut cropping systems													
Groundnut genotypes	Insecticide doses	Anthocoridae		Coccinellidae		Forficulidae		Mantidae		Lycosidae Agelenidae		Staphylinidae		Syrphidae	
		Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter
Igola I	Unsprayed	3.87 a	2.25 a	26.0 a	37.6 a	5.31 a	6.06 a	2.2 a	3.37 a	26.19 b	31.7 a	6.63 a	11.06 a	7.69 a	12.0 a
"	0.5 dose	0.94 c	0.44 c	11.19 b	10.44 b	1.00 c	1.06 c	0.63 b	0.56 b	10.44 a	14.5 c	1.06 b	3.13 b	4.56 b	3.25 b
"	Full dose	0.63 c	1.06 c	11.19 b	10.25 b	0.81 b	1.00 c	0.625 b	0.5 b	7.75 b	9.69 c	3.06 b	2.34 b	2.56 b	3.00 b
Erudurudu	Unsprayed	2.69 b	1.35 b	27.75 a	38.31 a	5.75 a	5.44 b	9.93 a	3.68 a	25.5 a	36.38 a	6.94 a	9.50 a	8.18 a	12.4 a
"	0.5 dose	0.37 c	0.31 c	12.31 b	10.56 b	1.00 c	1.19 c	0.50 b	0.90 b	11.5 b	11.44 b	2.06 b	3.87 b	3.88 b	4.75 b
"	Full dose	0.44 c	0.15 c	11.88 b	10.54 b	0.88 c	0.81 c	0.56 b	0.50 b	9.75 b	9.38 c	3.38 b	2.56 b	2.31 b	2.81 b
CV (%)		61	51	20	17.4	39	37	41	42	31	28	30	26	24	20.5

b) Long rains, April-August, 2003

		Groundnut cropping systems																	
Groundnut genotypes	Insecticide doses	Syrphidae		Forficulidae		Mantidae		Lycosidae Agelenidae		Staphylinidae		Coccinellidae		Anthocoridae		Chrysopidae		Carabidae	
		Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter
Erudurudu	Unsprayed	8.23 a	12.2 a	4.5 b	7.5 b	5.7 b	4.8 b	11.25 a	13.9 a	5.35 b	7.8 b	7.8 b	10.0 b	1.8 a	3.9 a	3.4 a	5.3 a	15.6 a	17.8 a
"	0.5 dose	1.36 b	4.52 b	1.75 c	3.0 c	1.95 c	0.91 c	8.40 b	3.75 b	2.09 e	1.92 e	3.0 c	3.4 d	1.0 b	1.8 b	1.0 b	1.3 b	9.0 b	9.75 b
"	Full dose	1.57 b	3.71 b	2.25 c	2.5 c	1.7 c	1.1 c	6.12 c	4.5 b	2.20 e	1.98 e	3.0 c	3.4 d	1.3 ab	1.2bc	1.2 b	1.4 b	8.4 bc	7.8b c
Igola I	Unsprayed	7.7 a	11.5 a	7.37 a	9.5 a	6.4 a	7.91 a	12.9 a	14.3 a	8.30 a	10.5 a	15 a	12.7 a	1.4 a	1.9 b	4.0 a	5.0 a	17 a	17.4 a
"	0.5 dose	2.6 b	4.9 b	1.62 c	3.25 c	0.36 c	1.05 c	5.12 c	4.4 b	2.85 c	4.6 c	3.8 b	5.0 c	0.6 b	0.8 b	1.0 b	1.75 b	5.8 c	6.5 c
"	Full dose	2.21 b	4.2 b	1.37 c	3.62 c	0.1 cd	1.07 c	3.5 d	4.5 b	2.56 cd	3.3 d	4.5 b	5.6 c	0.5 b	1.2b c	1.0 b	0.88 b	6.6 bc	3.55 dc
CV (%)		18.1	20.4	24.4	20.3	22.1	19.7	23.5	21.4	13.5	13.1	18.8	22.4	27.8	27.8	39.3	41.1	28.7	24.3

Mono = Monoculture (groundnut sole); Inter = Intercropping (groundnut + maize).

Unsprayed = Control; 0.5 dose (half dose) = 12.5 ml Dimethoate + 5 ml Cypermethrin; Full dose = 25 ml Dimethoate + 10 ml Cypermethrin.

Within each column, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for means separation. CV(%) = coefficient of variation in percentage.

Table 2. Effects of groundnut genotypes, cropping systems and insecticide sprays on the population density of arthropod predators, Mulungu Research Center, eastern DRC.

a) Long rains, November, 2002 -March, 2003

Groundnut genotypes	Insecticide doses	Groundnut cropping systems																			
		Syrphidae		Forficulidae		Mantidae		Lycosidae Agelenidae		Staphylinidae		Coccinellidae		Anthocoridae		Chrysopidae		Bdellidae		Carabidae	
		Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter
GL24	Unsprayed	3.57 a	5.22 a	2.41 a	4.5 a	1.1 a	1.95 a	8.93 a	13.7 a	6.17 a	5.05 a	7.00 a	8.53 a	2.4 a	3.6 a	2.21 a	3.03 a	5.27 a	4.13a	16.3 a	14.11 a
"	0.5 dose	1.61 b	2.42 b	1.24 b	2.2 6	0.0 b	1.08 b	6.87 b	8.67 b	3.9 b	2.06 b	3.67 b	5.93 b	2.09 b	2.64 b	1.46 a	2.27 a	3.47 b	2.2 b	112.8 b	10.91 b
"	Full dose	1.45 b	1.60 b	1.47 b	1.33 c	0.0 b	1.15 b	6.4 b	8.87 b	2.77 b	3.41 b	2.53 b	1.33 c	1.68 b	2.78 b	1.15 a	2.15 a	3.47 b	2.27 b	12.7 b	9.4 b
Bunyakiri	Unsprayed	3.72 a	5.5 a	1.47 a	3.7 a	1.56 a	3.02 a	9.2 a	14.3 a	6.05 a	4.95 b	6.13 a	8.07 a	2.96 b	3.27 a	3.08 a	2.89 a	6.73 a	4.8 b	10.3 a	8.09 c
"	0.5 dose	1.72 b	1.72 b	1.15 a	2.82 b	0.0 b	1.09 b	3.67 b	5.7 b	3.82 b	3.32 b	3.73 b	5.00 b	2.05 a	1.64 b	2.33 b	1.50 b	5.4 b	2.73 b	15.4 a	13.7 a
"	Full dose	1.53 b	1.66 b	1.17 a	2.18 b	0.0 b	1.05 b	3.53 b	5.5 b	3.4 b	2.73 b	1.2 b	3.73 b	1.93 a	1.4 b	2.4 b	1.23 b	3.8 b	2.8 b	8.7 b	11.7 b
CV (%)		31.8	32.6	38.2	36.7	50.8	48.9	33.2	31.2	44.9	41.7	45.9	41.6	45	41.5	34.2	36.9	39.7	30.2	14.7	14.9

a) Short rains, March -June, 2003

Groundnut genotypes	Insecticide doses	Groundnut cropping systems																			
		Syrphidae		Forficulidae		Mantidae		Lycosidae Agelenidae		Staphylinidae		Coccinellidae		Anthocoridae		Chrysopidae		Bdellidae		Carabidae	
		Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter	Mono	Inter
GL24	Unsprayed	8.6 a	14.7 a	24 a	20 a	12.9 a	10.6 a	75.1 a	55 a	9.1 a	15 a	39 a	58 a	5.3 a	2.4 a	3.4 a	6.5 a	24.0 a	14.0 a	45 a	59 a
"	0.5 dose	4.2 b	1.0 b	1.5 b	5.0 b	2.4 b	5.6 b	51 b	31 b	5.0 b	9.9 b	20 b	35 b	2.0 b	0.0 b	1.1 b	1.2 b	23.0 a	16.0 a	40 a	20 b
"	Full dose	1.0 c	0.0 b	1.2 b	0.0 c	2.1 b	6.1 b	27 c	29 b	5.1 b	9.0 b	22 b	32 b	0.0 c	0.0 b	1.1 b	1.1 b	22.0 a	17.1 a	41 a	29 b
Bunyakiri	Unsprayed	9.1 a	15.1 a	25.1a	29.4 a	11.5 a	11.7 a	73.1 a	57 a	8.3 a	16.4 a	44 a	64 a	5.7 a	2.7 a	3.6 a	7.2 a	24.0 a	15.0 a	41 a	66 a
"	0.5 dose	3.4 b	0.2 b	4.9 b	8.0 b	1.3 b	8.1 b	45 b	17 b	3.0 b	10.4 b	16 b	39 b	0.0 b	1.8 b	0.3 b	9.5 b	22.0 a	18.0 a	37 a	55 a
"	Full dose	0.0 c	1.0 b	1.0 c	5.1 b	1.1 b	6.9 b	40 b	16 b	3.1 b	10.1 b	17.4 b	40.5 b	0.0 b	0.0 c	0.2 b	2.4 b	23.0 a	19.0 a	34 a	59 a
CV (%)		54.5	45.1	19.7	29.4	47	39	14	10.7	34	39.5	21	29	57	55.7	41	42	10.7	19.5	13.4	14.5

Mono = Monoculture (groundnut sole); Inter = Intercropping (groundnut + maize).

Unsprayed = Control; 0.5 dose (half dose) = 12.5 ml Dimethoate + 5 ml Cypermethrin; Full dose = 25 ml Dimethoate + 10 ml Cypermethrin.

Within each column, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for means separation. CV(%) = coefficient of variation in percentage.

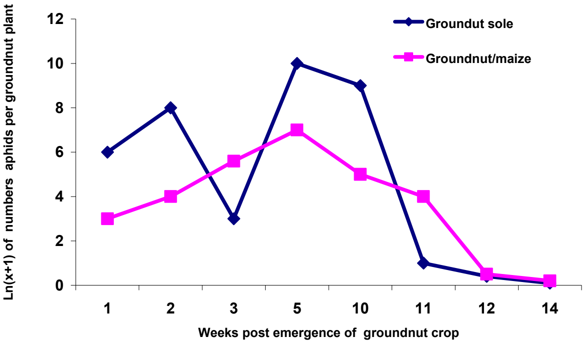

Figure 1. Fluctuation of aphids population density in unsprayed plots as being influenced by groundnut cropping systems, Kumi, eastern Uganda, long rains, 2003: Data are means of the two genotypes cultivated.

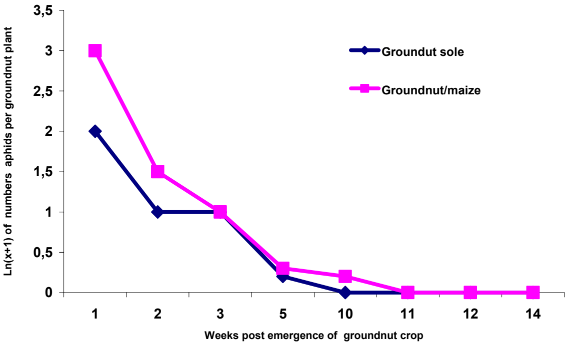

Figure 2. Fluctuation of aphids population density in sprayed plots of groundnut monoculture and polyculture systems, Kumi, eastern Uganda, long rains, 2003: Data are means of the two groundnut genotypes cultivated.

Table 3. Effect of groundnut cropping systems and insecticides on the fluctuation of the population density (number of thrips per 5 groundnut shoots) of thrips (*F. schultzei*).

a) Bukkedea, Kumi district, eastern Uganda, long rains (April-August): data are means of years 2002 and 2003. Data presented are also means of the two groundnut genotypes cultivated in the study site

Weeks post emergence of the groundnut crop	Groundnut cropping systems					
	Groundnut sole			Groundnut/maize		
	Unsprayed	0.5 dose	Full dose	Unsprayed	0.5 dose	Full dose
2	16.1 c	6.2 a	3.4 c	18.6 d	26.5 a	30.5 a
4	08.1 d	5.1 b	4.2 b	35.1 b	5.8 c	9.3 c
6	14.3 c	3.7 c	7.2 a	38.3 b	5.3 c	21.4 b
8	18.4 b	5.8 b	3.2 c	27.3 c	3.3 d	23.6 b
10	21.9 b	8.6 a	1.7 d	48.7 a	10.3 b	3.6 e
12	28.2 a	7.7 a	0.2 e	51.5 a	5.6 d	4.5 d
14	32.3 a	4.6 b	0.4 e	32.4 b	8.6 b	3.5 e

b) Mulungu Agricultural Research Station, South-Kivu Province, and eastern DRC: data are means of long and short rains 2003. Data presented are also means of the two groundnut genotypes cultivated

Weeks post emergence of the groundnut crop	Groundnut cropping systems					
	Groundnut sole			Groundnut/maize		
	Unsprayed	0.5 dose	Full dose	Unsprayed	0.5 dose	Full dose
2	8.1 d	3.2 a	1.8 b	5.9 e	2.7 e	2.8 c
4	6.2 d	2.3 b	1.9 b	7.5 d	1.5 f	0.2 e
6	11.1 c	2.2 a	2.3 a	10.2 c	7.6 c	1.4 d
8	12.3 c	3.2 a	0.2 c	5.6 e	4.5 d	1.2 d
10	24.4 b	1.3 c	1.5 a	16.7 b	11.2 a	5.2 a
12	27.2 a	2.4 b	1.4 b	19.8 a	6.5 c	3.8 b
14	22.1 b	2.5 b	0.9 b	16.2 b	9.6 b	4.6 a

Unsprayed = Control; 0.5 dose (half dose) = 12.5 ml Dimethoate + 5 ml Cypermethrin; Full dose = 25 ml Dimethoate + 10 ml Cypermethrin.

Within columns, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for means separation.

Discussion

Abundances of different predator taxa were significantly (P<0.05) affected by the cropping systems and insecticide doses. The effect of groundnut genotype was not significant (P>0.05) for most predators.

In this study, it was observed that groundnut/maize polyculture supported higher numbers of predators than did groundnut monoculture. These findings are in agreement with conclusion of studies conducted elsewhere examining the complexity of predaceous arthropods in peanut fields and other pulse crops (Agnew and Smith, 1989; Burgess and Collins, 1911; Mangold, 1979; Shecthan, 1986).

For example, Mack *et al.* (1991) found that *Coleomegilla maculata* (De Geer) (Coleoptera Coccinellidae), *Oxyopes salticus* Hentz (Araneae Oxyopidae) and *Labidura riparia* (Pallas) (Dermaptera Labiduridae) were more abundant in groundnut polyculture than in monocultures in Florida (USA). Similarly, in Central

Table 4. Effects of groundnut cropping systems and insecticide applications on the fluctuation of the population density (number of pupae and all larvae instars per 50 groundnut leaves) of leafminer (*A. modicella*).

a) Bukkedea, Kumi district, eastern Uganda, long rains (April-August): data are means of years 2002 and 2003. Data presented are also means of the genotypes cultivated

Weeks post	Groundnut cropping systems					
emergence of the	Groundnut sole			Groundnut/maize		
groundnut crop	Unsprayed	0.5 dose	Full dose	Unsprayed	0.5 dose	Full dose
4	30.1 a	4.3 b	3.1 a	14.2 a	2.6 d	3.7 a
6	13.6 c	2.4 d	2.9 b	4.4 c	5.7 b	2.9 b
8	20.8 b	5.4 a	0.6 c	7.6 b	3.5 c	1.6 c
10	28.2 a	4.8 a	2.6 a	17.1 a	8.6 a	0.8 d
12	24.6 a	3.9 c	2.7 a	9.7 b	4.9 b	1.3 c

b) Mulungu Agricultural Research Station, South-Kivu Province, eastern DRC: data are means of long and short rains of year 2003. Data are also means of the genotypes

Weeks post	Groundnut cropping systems					
emergence of the	Groundnut sole			Groundnut/maize		
groundnut crop	Unsprayed	0.5 dose	Full dose	Unsprayed	0.5 dose	Full dose
4	10.8 c	2.4 c	2.9 a	2.4 c	3.7 b	1.9 a
6	17.8 b	5.3 a	0.6 c	15.6 a	1.5 b	0.6 b
8	25.3 a	4.8 a	2.6 b	8.6 b	4.6 a	0.8 b
10	21.6 a	3.9 b	2.8 a	6.7 b	3.2 b	0.3 c
12	14.5 b	0.3 d	0.1 d	0.6 d	0.51 c	0.6 b

Unsprayed = Control; 0.5 dose (half dose) = 12.5 ml Dimethoate + 5 ml Cypermethrin; Full dose = 25 ml Dimethoate + 10 ml Cypermethrin.

Within columns, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for means separation.

Table 5. Effects of cropping systems and insecticide applications on groundnut yield (t/ha).

a) Bukkedea, Kumi district, eastern Uganda

Insecticides	Groundnut cropping systems							
	Groundnut sole				Groundnut/maize			
	Long rains, 2002		Long rains, 2003		Long rains, 2002		Long rains, 2003	
	Igola I	Erudurudu	Igola I	Erudurudu	Igola I	Erudurudu	Igola I	Erudurudu
Unsprayed	0.68 c	0.53 c	0.97 c	0.69 b	0.67 c	0.97 b	0.78 c	0.57 b
0.5 dose	1.82 b	1.77 b	2.31 a	2.17 a	2.16 b	1.89 a	1.26 b	0.89 a
Full dose	1.96 a	2.13 a	2.01 b	2.11 a	2.33 a	1.98 a	1.33 a	1.28 a

b) Mulungu Agricultural Research station, South-Kivu province eastern DRC

Insecticides	Groundnut cropping systems							
	Groundnut sole				Groundnut/maize			
	Long rains, 2003		Short rains, 2003		Long rains, 2003		Short rains, 2003	
	GL 24	Bunyakiri	GL 24	Bunyakiri	GL 24	Bunyakiri	GL 24	Bunyakiri
Unsprayed	0.73 b	0.57 b	0.59 c	0.41 c	0.93 b	0.55 b	0.43 b	0.35 b
0.5 dose	1.65 a	1.94 a	1.32 b	1.29 b	1.17 a	1.90 a	1.26 a	0.95 a
Full dose	1.72 a	2.05 a	1.42 a	1.37 a	1.22 a	1.87 a	1.30 a	1.17 a

Unsprayed = Control; 0.5 dose (half dose) = 12.5 ml Dimethoate + 5 ml Cypermethrin; Full dose = 25 ml Dimethoate + 10 ml Cypermethrin.

Within columns, means followed by the same letter are not significantly different at 5% probability level as determined with Fisher's protected least significant difference (LSD) test for means separation.

Mexico, ladybirds (*Hippodamia* sp.) were reported to be abundant in maize-bean polycultures than in corn monocultures (Obrycki and Kring, 1998).

There are many ecological factors that may empower polyculture to attract high numbers of predators (Andow and Rish, 1985; Altieri and Letourneau, 1982).

Taxonomically diverse plant habitats (groundnut/maize, etc.) often provide microclimates, greater availability of food sources (e.g, prey, pollen, nectar), alternatives hosts, and shelter/breeding sites that encourage colonization and population build-up of natural enemies (Coll and Bottrell, 1995; Dempster and Coaker, 1994; Letourneau and Altieri, 1983; Perrin, 1980).

In addition it was observed during the course of this study that earwig predators preferred habitats with higher humidity and lower temperature in order to lay their eggs on shaded parts of maize plants (Munyuli, personal observation).

Highlights from our study indicate that groundnut genotypes had little influence on the abundance of predator species.

Similar results have been reported by studies conducted elsewhere in USA, Africa and in Asia on peanut and other pulse crops (Burgess and Collins, 1911; Mangold, 1979; Andow and Rish, 1995; Altieri and Letourneau, 1982; Cromatie, 1981).

In this study, lower populations of aphids, thrips and pod borers, higher yields and high abundance of predators were observed to be associated with the groundnut/maize system. This indicates that this system is good for small scale groundnut producers since it can provide a farmer with higher or acceptable yields, even if the farmer did not apply insecticides. Maize genotypes gave similar trends in both study sites. The higher numbers of predators in groundnut/maize could be due to the crop canopy providing more food and, shade to allow development of their different stages (eggs, larvae). Similar observations were noted by Kumar (1993), Kumaraswami (1991), Lakkundi (1989), Sahayaraj (1991) and Kalyanasundaram *et al.* (1994) during their studies aiming at understanding the factors influencing the abundance and diversity of predators in groundnut based cropping systems in India.

The greatest number of predator species was found in the DRC site probably because the surveyed area (Mulungu) had more rains, a diversity of refuge habitats and alternative host plants found at edges and field margins of cultivated plots. All these habitats that surrounded the experimental trials are attractive for many generalist predators. At Kumi this diversity of habitat was not very high.

Geographical, ecological and climatic variations may be also responsible for the differences observed in predator activity, abundance and species diversity between DRC and Uganda. Apart from their influence on the synchronization of predators and prey, seasonal changes in climatic conditions substantially affect the distribution of predators by changing the microclimatic characteristics of habitats and by influencing the growth of prey populations through the physiology of plants (Iperti, 1999).

Population densities of arthropod predators were significantly ($P<0.05$) reduced in sprayed plots. Clearly, the most significant factor disrupting biological control of arthropod pests in groundnut cropping system is the use of insecticides such as cypermethrin and dimethoate. Similar effects of cypermethrin and dimethoate insecticides on natural enemies' population were previously reported by Kannan (2000).

In fact, it has been demonstrated that Cypermethrin and Dimethoate kill predators significantly on cotton and cowpea in Nigeria (Kannan, 2000; Parell *et al*., 1984). These two insecticides are not friendly to indigenous natural enemies and to the environment despite the fact that they are effective in controlling pests' population.

Because insecticides are likely to remain a major component of pest suppression in IPM systems, minimizing the effects of these insecticides on natural enemies in cropping systems will require more attention in eastern and central Africa. Further development of IPM systems in different ecological areas of Africa continues to be needed. There is also a need to understand and measure area requirements for beneficial arthropod such as predators to provide agro-ecological services of high quality in terms of field pests control under local agro-ecosystem environments. For instance, it is recommended to farmers from the study sites to intercrop groundnut and maize whenever they have to grow groundnut. This technology is environmental friendly, appropriate and easier to integrate into local farming practices. Scaling-up technologies such as groundnut/maize is one of the ways to conciliate biological control/environmental conservations with groundnut production.

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