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Effects of Sowing Date Modification and Intercropping on the Distribution of *Aphis craccivora* Koch (Hemiptera: Aphididae) in Groundnut (*Arachis hypogaea*) in the Nigerian Sudan Savanna and Implications for Management

B.M. SASTAWA[1], Y.T. MAINA AND M. LAWAN
Department of Crop Protection, Faculty of Agriculture, University of Maiduguri, P.M.B. 1069, Maiduguri, Nigeria
[1]Corresponding author's e-mail: bsastawa@yahoo.co.uk

ABSTRACT

Field trials were conducted during the 2001 and 2002 cropping seasons to determine the distribution pattern of *Aphis craccivora* in groundnut fields in Maiduguri, Nigeria. The factorial experiment consisted of four sowing dates of groundnut (31 July and 7, 14 and 21 August in 2001 and 21, 28 July, 4 and 11August in 2002), four intercrop patterns (3:1, 2:1, 1:1 and 0:1) of millet to groundnut and 2 intercrop systems of millet-groundnut (MG) and millet-groundnut-soybean-cowpea (MGSC) arranged in split-split plot design. Aphids and their predator (*Cheilomenes vicina*) were present in groundnut fields for about five weeks in both 2001 and 2002. However, the numbers of aphids and those of their predator were not significantly ($p > 0.05$) correlated. The distribution pattern of aphids in groundnut sown on the different dates and as intercrops was regular ($b<1$) according to Taylor's Power Law; conversely, aphids in sole groundnut assumed a clumped ($b>1$) distribution. There were significant ($p\leq0.05$) correlations between mean number of aphids/ plant and percent incidence of infestation. Differences between the expected and the observed proportions of groundnut plants infested by aphids were not significant ($p > 0.05$) over the two cropping seasons.

Key Words: Pest management; *Aphis craccivora;* Groundnut; Nigerian Savanna

INTRODUCTION

The evolution of adaptive life-cycles by insects is an important strategy by which insects cope with the selective pressures of their environment. In the ephemeral agricultural systems of the tropics, important strategic adaptations for coping by insects include those for high rates of increase and high powers of dispersal. Dispersal, the seasonal abundance and spatial distribution of insect species (Southwood, 1978; Horn, 1988), is an adaptive strategy by which insects avoid overcrowding, enhance their potential for the colonization of habitats and increase their evolutionary plasticity (Blackman & Eastop, 1984; Horn, 1988). Undoubtedly, these behavioural processes and biological attributes are vital in the insect's life cycle and thus could play significant roles in the management of the pest species among the insects. Already, there are strong indications that informal methods of strategic control (for example, altering sowing dates and changing crop varieties) can only be relevant in sustainable pest management programmes with adequate knowledge of pest dispersal (Tingey & Lamont Jr., 1988; Tatchell, 1991; Renolds *et al*., 1999). This is more crucial in crop fields where insect dispersal is known to change the potential of insect pests for crop infestation (Moss *et al*., 1982; Hodkison & Hughes, 1982; Horn, 1988). Therefore, pest management options that minimize insect dispersal are desirable and these are usually biointensive approaches that rely much on the manipulation of the plant or its environment (Davidson & Lyon, 1979; Jackai, 1993; FMANR/ ODA, 1996; Lale, 2002).

In Nigeria, the manipulation of the complex traditional farming systems, where crop culture is varied both in spatial and temporal dimensions, is often employed, among other methods, to reduce the menace of aphid at the subsistence farm levels. However, the abundance and dispersal of insect species in space is influenced by the form of the distribution of the population of the species (Southwood, 1978). The objective of this study was to assess the abundance and pattern of distribution of *Aphis craccivora* in groundnut and the implication of the trends of the patterns on the management of the aphids.

MATERIALS AND METHODS

Designs and layouts. Field experiments were carried out at the Teaching and Research Farm of the Faculty of Agriculture, University of Maiduguri, in 2001 and 2002 cropping seasons: Maiduguri lies on Latitude 11^0N and Longitude 15^0 E.

The planting materials were: millet (var. Sosat), groundnut (aphid susceptible Cv. Ex-dakar), soybean (var.

Samsoy-2) and cowpea (aphid resistant var. IT89-KD-374-57; Singh *et al*., 1997). The seeds were obtained from the agricultural development programmes of Borno and Yobe states (Nigeria) and the Lake Chad Research Institute (Nigeria). The factorial experiment consisted of four sowing dates (31 July, August 7, 14 and 21 in 2001 and 21, 28 July, August 4 and 11 in 2002; the commencement of sowing in each year was based on when the rainfall established) (main plots)of groundnut, four intercrop patterns (3:1, 2:1, 1:1, 0:1) (subplot)of millet to groundnut and two intercrop systems of millet-groundnut (MG) and millet-groundnut-soybean-cowpea (MGSC) (sub-sub plot). The 32 (4 x 4 x 2) treatment combinations were each allocated to a plot of 4 m x 6 m in a block and replicated three times. Millet was sown on 31 July in 2001 and on 21 July in 2002. Groundnut was sown into millet on either 31 July (2001) or 21 July (2002) and then subsequently at weekly intervals for another three weeks. Sole groundnut (0:1) was sown at 50 cm between rows and 30 cm within rows. The sowing distance between millet and groundnut and between groundnut and groundnut was 50 cm in a row, with four rows of groundnut/ plot. Crops were maintained following the recommendations of BOSADP (1993) for the study area.

Sampling and estimation of the numbers of aphids and aphid predators in the field. Sampling for both the aphids and their coccinelid predator, *Cheilomenes vicina* was done once every week beginning from seven days after the first appearance of aphids in the field; *C. vicina* was named as an important aphid predator in Nigeria (Dike, 1992; Waba, 2000). The numbers of aphids were determined on plants in the outside rows of each plot. Two leaflets from the base and one leaflet from the top were sampled on each plant for aphids (*Aphis craccivora* prefer mature or tenderly young leaves of groundnut for infestation; Abubakar, 1988; Umaru *et al*., 1988; Izge *et al*., 2002). The aphids were dislodged from their host with a fine hair brush soaked in dilute soap solution. The aphids were collected in a vial containing 70% alcohol and thereafter counted in the laboratory without separating the different morphs.

The numbers of the aphid predators were counted / plot. The numbers were estimated by carefully looking for both adult and larvae within plant canopies (adult beetles usually hibernate under the leaves and larvae are usually found near or within aphid colonies). Both adults and larvae were counted *in situ* using a tally counter. Samples of adults were collected using sweep net and then preserved in 70% ethanol while samples of aphids and larvae of the predators were preserved in 70% ethanol + 5% lactic acid before identification at the Institute for Agricultural Research, Ahmadu Bello University, Zaria.

Data Analysis. The distribution of *Aphis craccivora* in groundnut sown on the different dates and in the different intercrops was determined using Taylor's Power Law (Taylor, 1961) given by the regression of log variance on log mean as: $\text{Log } s^2 = b \log x + \log a$, where s^2 is the variance, a is the intercept and, b is the slope and is a species specific aggregation factor (Taylor, 1961). When the value of b >1 the distribution pattern of the species is clumped (i. e. species are aggregated in space), when b = 1 the species is distributed randomly, (i.e the occurrence of an individual species in a unit space or habitat is independent of any other) and when b<1 the distribution of the species is regular (i.e., species are uniformly or evenly distributed in space) (Taylor, 1961; Southwood, 1978; Horn, 1988). The proportion of groundnut plants infested by aphids (a plant is considered to be infested if it had 1 aphid) was predicted using the equation from Wilson and Room (1983) as:

$$P(I) = 1 - \exp\{-x \ (\log e\, ax^{b-1}) * ax^{b-1} - 1\},$$

Where,

P (I) = the proportion of aphid infested groundnut plants
x = mean number of aphids/ plant
a = intercept from Taylor's Power Law
b = slope from Taylor's Power Law

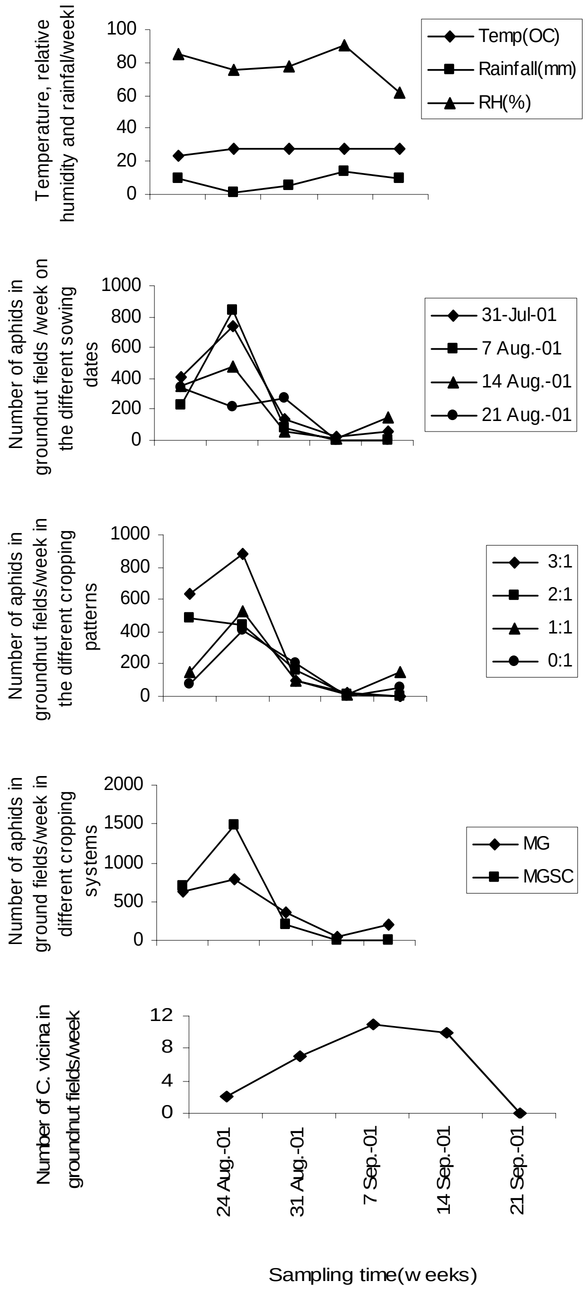
It was hypothesized that the observed proportion of plants infested (from sample data) was as expected or predicted (P (I) from the above equation) and this was tested using the χ^2 test (Clarke, 1980) as suggested by Godfrey and Chaney (1995). Simple correlation was established between the number of aphids/ plant and percent incidence of infestation (Snedecor & Cochran, 1978). Percent incidence of infestation (%) was estimated as:

$$\frac{\text{Number of plants infested by aphids in sample} \times 100}{\text{Total number of plants in sample}}$$

RESULTS AND DISCUSSION

In 2001 (Fig. 1), two peaks of aphids occurred on 31 August (first peak) and on 21 September (second peak) with the number of aphids being higher in groundnut sown on 7 August and 14 August, respectively than those sown on the other dates. In 2002 (Fig. 2), aphids rose to their only peak on 21 August, with the groundnut sown on 21 July having relatively higher number of aphids than those sown on the other dates. Peak aphid infestation occurred 1 month (21 July or 31 August) after the initial sowing date regardless of whether groundnut was sown early (2002) or was delayed (2001); however, heavier infestation, on average, occurred when groundnut was sown early in the season (2002) than when sown lately (2001). The results suggest that staggered sowing can influence both the intensity (build-up) and the spread (dispersal) of aphid infestation in groundnut. Aphids were regularly (b<1) distributed in groundnut sown on the different dates over the two cropping seasons (Table I); regular distribution is associated with reduced dispersal and colonization by pest species (Southwood, 1978; Horn, 1988). In both 2001 and 2002, peak aphid population occurred when groundnut plants of all ages were in the field (Fig. 1 & 2) so that the dispersing aphids would have concentrated its population on only a few of the host plants that were at the most preferred susceptible age to colonise among the plants of the different ages; however, crowding causes individuals in a population to move away from each

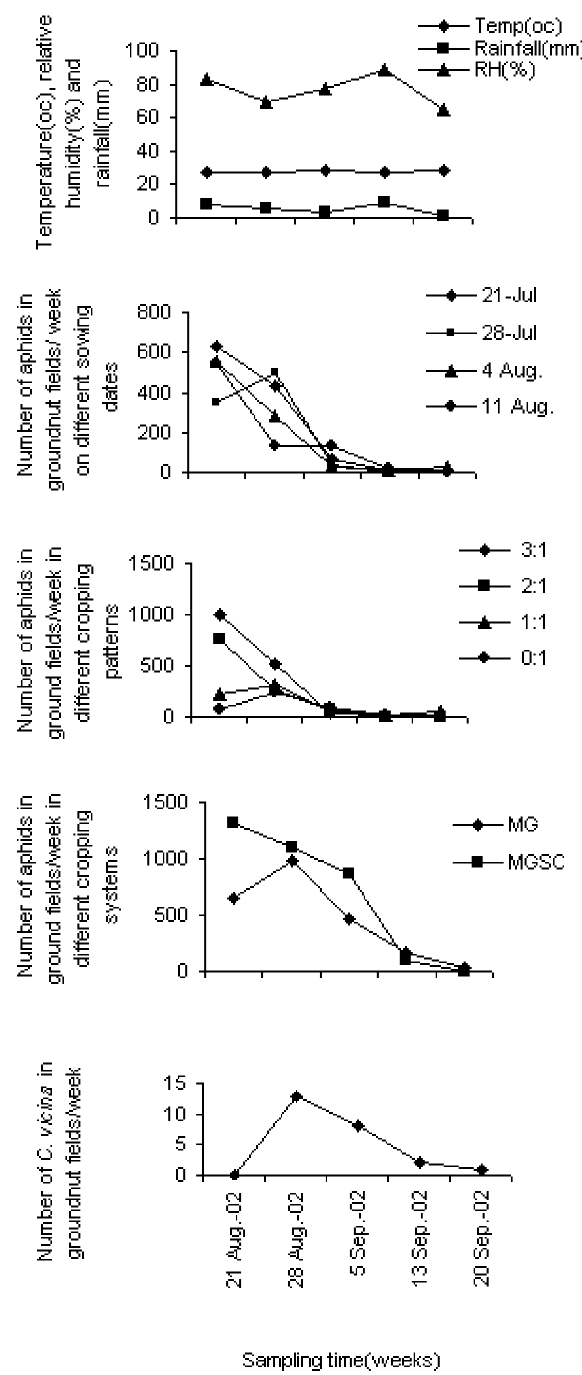
Fig. 1. Changes in temperature, relative humidity, rainfall and numbers of aphids and aphid predators in groundnut in Maiduguri during the 2001 cropping season



other to assume regular distribution in space (Southwood, 1978; Youdeowei & Service, 1983; Horn, 1988). In addition, it was possible that visual stimuli (attractiveness) and physical stimuli (plant surface) may have differed with age of groundnut plants and these may have restricted the aphids to recognize and select/colonise only those plants that elicited the appropriate cues; aphids are highly sensitive to stimuli (Southwood, 1978; Hodkison & Hughes, 1982).

Similar effects may have partly accounted for the regular distribution pattern of the aphid in intercropped groundnut. The peak aphid infestation in groundnut

Fig. 2. Changes in temperature, relative humidity, rainfall and numbers of aphids and aphid predators in groundnut in Maiduguri during the 2002 cropping season



intercropped in pattern 3:1 and in MGSC system (Fig. 1 & 2) may have been as a result of the few groundnut plants in these intercrops than in the 2:1, 1:1 and MG intercrops. However, another mechanism by which dispersal was likely reduced in intercropped groundnut may have been as a result of the fact that the number of colonizing aphids were physically reduced by the barrier crops, particularly millet that were intersown with the groundnut, possibly by intercepting and/ or constricting the migrating aphids. The net effects of all these are that; firstly, aphids are prevented from aggregating and this reduces the potential of the aphids to reproduce and to form dispersing morphs and secondly, aphids that land on non-host plants such as millet in the intercrop are likely to lose their virulence, since the relationship between the aphid and the virus is semi-persistent (Umaru *et al*., 1998). The significantly ($p \leq 0.05$) higher correlation ($R^2 = 0.94$) between the number of aphids/ plant and percent incidence of infestation suggests that there may have to be preponderantly higher aphid numbers for any reasonable level of infestation to occur in intercropped groundnut. Intercropping systems are known to regulate pest numbers in crop fields partly by increasing the amount of energy required by the pest to find its host as well as by optimizing synchrony between natural enemies and their target host pest species (Steiner, 1984; Bhatnagar & Davies, 1981; IITA, 1989).

In this study, the correlations between the mean number of *Aphis craccivora* and their coccinelid predator were not significant in both 2001 ($R^2 = 0.60$, $p > 0.05$, d f = n-2 = 3) and 2002 ($R^2 = 0.01$, $p > 0.05$, d f = n-2 = 3) which may be attributed to the generally low population of the predators in both years. The results imply that the observed reductions in the number of aphids following increases in the numbers of their predator or vice-versa (Fig. 1 & 2) was

Table I. Taylor's Power Law coefficients for *Aphis craccivora* in groundnut sown on different dates and as intercrops at Maiduguri, 2001 and 2002

2001				2002				Combined years (2001 and 2002)		
Treatment	Mean number of aphids/ plant	Regression coefficients		Treatment	Mean number of aphids/ plant	Regression coefficients		Mean number of aphids/ plant	Regression coefficients	
		a	b			a	b		a	b
				Sowing Date						
31July 2001	38.3			21 July 2002	40.0			41.0		
7 Aug. "	25.4	} 0.67	0.41	28 " "	27.6	} 0.79	0.22	27.4	} 0.64	0.57
14 " "	24.2			4 Aug. "	26.6			23.3		
21 " "	18.3			11 " "	17.6			17.9		
				Intercrop pattern						
3:1	30.8			3:1	36.7			33.9		
2:1	29.4	} 0.73	0.21	2:1	24.8	} 0.67	0.52	28.5	} 0.73	0.30
1:1	12.4			1:1	15.6			13.2		
0:1	12.9			0:1	13.0			13.9		
				Intercrop system						
MG	45.0	} 0.63	0.79	MG	54.0	} 1.01	0.70	50.2	} 0.72	0.53
MGSC	48.3			MGSC	69.0			59.4		
				Sole groundnut						
	11.7	} 1.62	0.39		12.9	} 1.66	1.87	14.1	} 1.68	1.28

Table II. Proportion* of groundnut plants infested by *Aphis craccivora* at Maiduguri, 2001 and 2002 (d f = n – 2 = 30)

	2001				2002			Combined years (2001 and 2002)		
Treatment	P(I)	p(o)	χ^2	Treatment	P(I)	p(o)	χ^2	P(I)	p(o)	χ^2
				Sowing date						
31July 2001	0.3404	0.4779	0.1583	21 July 2002	0.7952	0.5025	0.1077	0.7585	0.5000	0.0880
7 Aug. "	0.7924	0.2955	0.3131	28 " "	0.7451	0.3015	0.2641	0.5071	0.2898	0.0931
14 " "	0.1589	0.1257	0.6258	4 Aug. "	0.8284	0.0854	0.6664	0.7219	0.1080	0.5220
21 " "	0.8314	0.1006	0.6423	11 " "	0.6474	0.1105	0.4452	0.6432	0.1023	0.4548
				Intercrop pattern						
3:1	0.6299	0.2681	0.2078	3:1	0.0655	0.2806	0.7061	0.8838	0.3771	0.2905
2:1	0.8922	0.2793	0.4210	2:1	0.0726	0.2908	0.6558	0.6084	0.3440	0.1149
1:1	0.5757	0.3910	0.0590	1:1	0.6370	0.3520	0.1273	0.7156	0.2216	0.3410
0:1	0.1699	0.0614	0.0692	0:1	0.2878	0.0765	0.1551	0.7516	0.0573	0.6413
				Intercrop system						
MG	0.9999	0.5833	0.1735	MG	0.8679	0.6010	0.0820	0.4630	0.5966	0.0385
MGSC	0.2506	0.4166	0.1099	MGSC	0.6865	0.3989	0.1204	0.8897	0.4034	0.2658
				Sole groundnut						
	0.9999	0.4545	0.5495		0.9861	0.5625	0.5389	0.9999	0.7924	0.5430

Differences between p (I) and p (o) are not significant ($p>0.05$) according to the χ^2 test.

Fig. 3. Relationship between log variance and log mean of number of aphids in sole groundnuts (2001 and 2002)

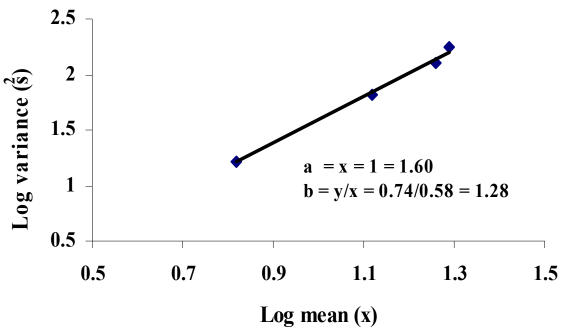


Fig. 4. Relationship between log variance and log mean of number of aphids in groundnuts sown on different sowing dates (2001 and 2002)

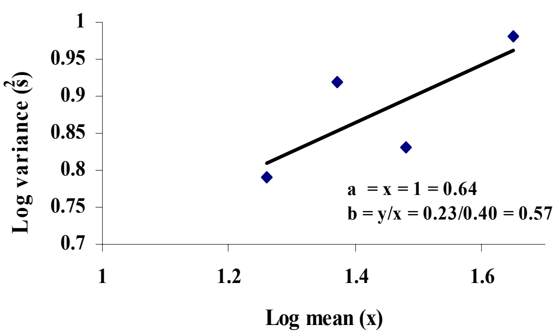
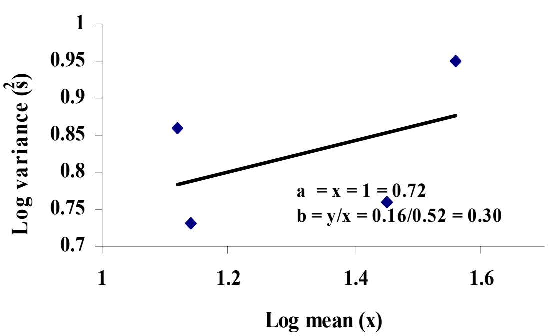


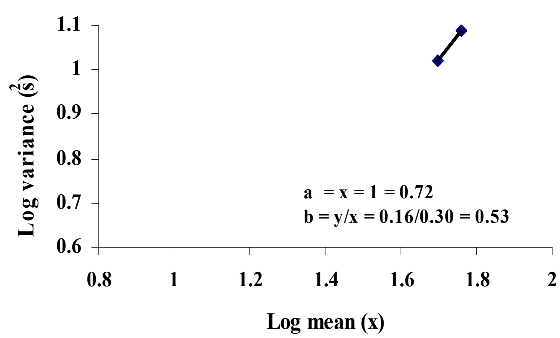
Fig. 5. Relationship between log variance and log mean of number of aphids in groundnuts intercropped in different patterns (2001 and 2002)



a weak association and the effects were probably not causative. It is known that some predators have little effects on their prey density (Davies, 1988). Nevertheless, target pests and their natural enemies are both highly dynamic populations (Bhatnagar, 1987), and differences may occur between the natural enemies and their host pests, in both biology and behaviour, that can influence the outcome of their interactions. Compared to the aphids that are r-strategists, the aphid predator's reproductive capacity is closely linked to the number of aphids (prey) that it can attack and this depends on its searching efficiency. The results suggest that *C. vicina*'s (aphid predator) efficiency for non-random search and its functional response capabilities (Varley *et al.*, 1973) were both low and this may have disarmed the predator from coping with the highly reproductive aphid population. It is already known that the stability of predator- prey interaction depends on the ability of the predators to devote much of their search time in areas of high density where hosts are aggregated (Youdeowei & Service, 1983). In addition, aphids were regularly distributed in intercropped groundnut (Table I) and this may have forced the aphid predators to search randomly; however, random search reduces both searching efficiency and handling time of a predator. The implication is that *C. vicina's* activity may have to be augmented for enhanced performance against *Aphis craccivora* under ephemeral agricultural systems.

On the other hand, the clumped (b >1) distribution pattern of the aphid in sole groundnut for the combined years (Table I) implies that this cropping system, irrespective of sowing date, favours faster development of the aphids. However, the significantly ($p \leq 0.05$) lower correlation ($R^2 = 0.46$) between the mean number of aphids/ plant and percent incidence of infestation indicate that increase in infestation intensity was accompanied by lower infestation incidence (Snedecor & Cochran, 1967) in sole groundnut and this may be accounted for by the fact that the aphids may have been migrating or dispersing from their point of location as their number/ unit space increased. The implication is that sole groundnut serves as a reservoir for dispersing aphids and subsequent colonization of crops. It is already known that ageing aphids orientate their behaviour first to migration and dispersal and secondly to colonization of new hosts (Blackman & Eastop, 1984). The results of this study suggest that these processes are more dominant and perhaps proceed faster in sole groundnut than in

Fig. 6. Relationship between log variance and log mean of number of aphids in groundnuts intercropped in two different cropping systems (2001 and 2002)



intercropped groundnut.

The differences between the observed and the expected proportion of groundnut plants infested by aphids (for the combined years) were not significant ($p > 0.05$) (Table II) and this indicates that, the observed proportion of the groundnut plants infested by aphids (from field sample) can be a predictor of the expected proportion of plants to be infested (Godfrey & Chaney, 1995). This implies that forcasting by sampling (Hill, 1983) can be an effective tool for taking decisions on the control of aphids in groundnut.

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