

INVESTIGATIONS ON TAXONOMY, BIOLOGY
AND CONTROL OF THE GROUNDNUT APHID,
APHIS CRACCIVORA KOCH. (HEMIPTERA : APHIDIDAE)

BY

ABD-AL-AZEEZ ABBA

A THESIS SUBMITTED TO THE DEPARTMENT OF CROP PROTECTION,
FACULTY OF AGRICULTURE, AHMADU BELLO UNIVERSITY, ZARIA,
IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE
OF MASTER OF SCIENCE.

MAY, 1981

APPROVED BY:

DR. S.R.SINGH
'Wprafraf. tfy'AivtT^Tte—
EXTERNAL EXAMINER

DR. A.K. RAHEJA
INTERNAL EXAMINER
(MAJOR SUPERVISOR)

DR. S. MISARI
INTERNAL EXAMINER

TABLE OF CONTENTS

TABLE OF CONTENTS	i
LIST OF TABLES	iii
LIST OF FIGURES	v
ACKNOWLEDGEMENT	vii
INTRODUCTION	1
LITERATURE REVIEW	3
Taxonomy	3
Distribution and host range	4
Life history	5
Pest/plant relationship and pest/disease/plant relationship	6
Aphid control	9
MATERIALS AND METHODS	12
Taxonomy	12
Aphid rearing	13
Life history	15
Nymphal growth and development	15
Fecundity	18
Pest/plant relationship and pest/disease/plant relationship	20
Aphid control	22
Glasshouse experiments	25
Field experiments	26

RESULTS AND DISCUSSIONS	29
Taxonomy	29
Life History	49
Nymphal growth and development	49
Fecundity	55
Pest/plant relationship and pest/disease/plant relationship	58
Aphid control	67
CONCLUSION	79
SUMMARY	81
APPENDICES	85
LITERATURE CITED	109

LIST OF TABLESTable

1	Acute oral and dermal LD ₅₀ 's for the insecticides used for aphid control	24
2	Measurements of body length, antenna, siphunculus and cauda and their ratios for <u>A. craccivora</u> (mm)	31
3	Measurements of antennal joints III, IV and VI, hind-tibia, fore-tibia and fore-tarsus and the number of secondary rhinaria of <u>A. craccivora</u> (mm)	32
4	Comparison of the measurements of various appendages of apterous viviparous female of <u>A. craccivora</u> obtained in different studies	45
5	Comparison of the measurements of various appendages of alate viviparous female of <u>A. craccivora</u> obtained in different studies (mm)	46
6	Comparison of the ratios of various appendages and body lengths of apterous viviparous female of <u>A. craccivora</u> obtained in different studies ..	47
7	Comparison of the ratios of various appendages and body lengths of alate viviparous female of <u>A. craccivora</u> obtained in different studies	48
8	Summary of the cumulative mean of exuviae per nymph of <u>A. craccivora</u> for three experiments	50
9	Mean daily temperature (°C) and mean daily % relative humidity of nymphal growth and development of <u>A. craccivora</u>	51
10	Mean duration (hours) of instars I - V of <u>A. craccivora</u>	53
11	Comparison of the reproductive life of apterous and alate viviparous females of <u>A. craccivora</u> ..	56

12.	Mean plant height per week and mean increase in plant height per week (mm)	60
13	Mean number of leaflets per week and mean increase in number of leaflets per week	61
14	Mean per cent mortality of non-viruliferous <u>A. craccivora</u> in the glasshouse experiment	69
15	Mean per cent mortality of non-viruliferous <u>A. craccivora</u> in the field experiment	70
16	Number of rosetted plants and days to the appearance of the rosette symptoms in the glass- house experiment	71-72
17	Number of rosetted plants and days to the appearance of the rosette symptoms in the field experiment	73-74

LIST OF FIGURES

<u>Figure</u>		
1	Apparatus for the study of the nymphal growth and development of the groundnut aphid, <u>A. craccivora</u>	16
2	Experimental set-up to study fecundity of aphids	19
3	Set up of the insecticide screening experiment in the glasshouse	29
4	Head and antenna of apterous and alate viviparous females of <u>A. craccivora</u>	33
5	Antennal segments I - IV of apterous viviparous female of <u>A. craccivora</u>	34
6	Antennal segments V and VI of apterous viviparous female of <u>A. craccivora</u>	35
7	Apical rostral segments of apterous viviparous female of <u>A. craccivora</u>	36
8	Abdomina of apterous viviparous female of <u>A. craccivora</u>	37
9	Abdomina of alate viviparous female of <u>A. craccivora</u>	38
10	Cauda of apterous viviparous female of <u>A. craccivora</u>	39
11	Cauda of alate viviparous female of <u>A. craccivora</u>	40
12	Siphunculus of apterous viviparous female of <u>A. craccivora</u>	41
13	Siphunculus of alate viviparous female of <u>A. craccivora</u>	42
14	Forewing of viviparous female of <u>A. craccivora</u> ..	43
15	Graphical representation of nymphal development of <u>A. craccivora</u> based on the mean numbers of exuviae produced each day	52

15	Fecundity (number of offspring produced per day) of apterous and alate viviparous females of <u>A. craccivora</u>	57
17	A Field of groundnut crop heavily infested with both the green and chlorotic rosette viruses ..	62
18	Green and chlorotic rosette on groundnut plants	63
19	Comparison of a healthy groundnut plant with those affected by the green and chlorotic rosette viruses	64
20	Groundnut plant in pot showing the green rosette symptoms	65
21	Groundnut plant in pot showing chlorotic rosette symptoms	66

ACKNOWLEDGEMENT

I am very grateful to my supervisor Dr. A. K. Raheja for his useful suggestions and guidance during the course of these studies. My sincere gratitude also goes to Dr. S. N. Misari for the keen interest he showed in these studies, and for his useful criticism and valuable suggestions during the greater part of these studies.

I also wish to thank Professor C. Harkness for providing the groundnut seeds used in the studies. I am grateful to Mr. J. C. Deeming (Curator) for his assistance in the identification of the groundnut aphid. I am very grateful to Dr. A. A. Ibrahim of the Agronomy Department for analysing the data.

I am also thankful to Messers Israel R. Agbakuru, Yusuf and Jacob for their assistance in one way or another during the course of the studies. I also wish to thank Mr. Sylvanus Anyanwu, Mallam Rabi'u Wada and Yahaya Abdullahi for typing the manuscript.

I am extremely indebted to the Kano State Government who sponsored this study and also to Alhaji Jibir Mudil, former Chief Agricultural Officer, now Special Adviser on Agriculture and Rural Development and his former deputy, Alhaji Musa Ringim for encouraging me to pursue this study.

Finally, I wish to acknowledge the love, affection and patience expressed by my wife Asama'u and my children, Amina and Ibrahim which inspired me throughout the period of these studies.

I N T R O D U C T I O N

Groundnut (Arachis hypogaea L.) is an important cash crop in Nigeria. It was introduced into the country from South America in the 16th Century. Before the advent of the drought of 1973 and the rosette disease epiphytotic of 1975, it was estimated that about 0.8 to 1.2 million hectares of groundnuts were grown annually (Harkness et al. 1976). The crop is grown in every state of the North, the bulk of it being concentrated in Bauchi, Borno, Gongola, Kaduna, Kano and Sokoto states (AERLS, 1977). Half of the Nigeria's groundnut crop is grown in Kano State (Abalu, 1976).

Groundnut at one time was Nigeria's greatest single agricultural export in the form of nuts, oil and cake (FAO, 1966). The 1973 drought and the rosette virus disease epiphytotic of 1975 caused a decline in groundnut production in Nigeria. The production was so low that the then Marketing Board recorded a zero purchase in each of the 1975/76 and 1976/77 seasons in Kano State. The decline in yield resulted in loss of confidence in the crop amongst farmers in the main growing areas of the country. Consequently land area devoted to groundnut was reduced as farmers switched to the production of other crops. For example, many

farmers in Gumel Local Government Area of Kano State switched to benniseed, Sesamum indicum, production (Mudil, 1978). In some districts in the 1970 season the acreage under benniseed even exceed that of groundnut (Davies, 1979).

The groundnut aphid is perhaps the most important pest of groundnut in Nigeria. Apart from causing direct injury to the crop by sucking plant juices from the plants, the aphids also transmit the groundnut rosette virus (GRV). Diseased plants express various symptoms ranging from mild chlorosis and mottling of leaves to severe distortion and stunting of aerial shoots. Pods may or may not be formed, and if formed, may be empty (Misari, 1975).

In spite of the importance of aphids as pests of groundnuts, not much work has been done on the bionomics and status of this insect as a pest of groundnuts in Nigeria. The work reported here may be seen as preliminary study to define the pest/host relationship and look at possibilities of its control and the virus disease transmitted by it. Various aspects included in this study

- are :
- (1) Taxonomy
 - (2) Life History
 - (3) a. Pest/Plant Relationship
b. Pest/Disease/Plant Relationship
 - (4) Chemical Control.

LITERATURE REVIEW

1. TAXONOMY

The groundnut aphid, Aphis craccivora Koch. (Hemiptera: Aphididae) was first described in 1854 by C. L. Koch. According to Cottier (1953), this species had been previously misidentified in the literature as A. laburni Kltb. and A. leguminasae Theobald.

Identification of this species is based on its colour pigmentation on the abdomen of the aptera, number of secondary rhinaria on the 3rd antennal segment, the body length and the respective lengths of the various appendages. Cottier (1953) gave the body length as 2.06 and 1.90mm for the aptera and alate respectively. Eastop (1961) gave a range of 1.50 - 2.00mm respectively, while Jones (1957) found the length of the aptera to be 1.69mm.

Different races of A. craccivora exist. Okusanya and Watson (1966) found that there are two clones of this species which differ in their ability to transmit the GRV₁ strain of the rosette virus. They were working with two clones, one from Nigeria and the other from Kenya. They found that both clones could transmit strains GRV₁ and GRV₂ but that only the Nigerian clone could transmit strain GRV₁.

Jones (1967) also working with two clones of A. craccivora, one originating from Nigeria and the other from Kenya, confirmed that the clones are different. She was able to distinguish the clones by body and limb measurements as well as by host colonization experiments. The latter showed that the Nigerian clone produced colonies more readily than the Kenyan clone on healthy plants of Onobrychus viciifolia, Gomphrena globosa and young Glycine max (L.). There was no significant difference between the two clones in terms of their fecundity on groundnut and Vicia faba (L.).

2. DISTRIBUTION AND HOST RANGE

A. craccivora is found in Africa, Argentina, Australia (New South Wales and Queensland), Chile and India (Feakin, 1973). Hill (1975) stated that the aphid is virtually cosmopolitan, but its records are rather sparse in some areas.

This species of aphid is polyphagous, but prefers to feed on the young shoots of leguminous plants (Feakin, 1973). In Northern Nigeria, Booker (1963) identified 15 species of cultivated and wild plants which serve as hosts for the aphid. Amongst these Euphorbia hirta (L.) (Euphorbiaceae) was the only host which was found to carry the aphid throughout

the dry season all over northern Nigeria. Recently, A. craccivora was identified on about 60 cultivated and wild plants (Akinfenwa, 1977). Among these, Gliricidia sepium (Jacq.) Walp; E. hirta and E. laterifolia were observed to host this aphid throughout the dry season.

3. LIFE HISTORY

The life-cycle of the aphids is influenced primarily by the type of climate. In the tropics reproduction is parthenogenetic and viviparous, whereas in the temperate regions it is by both sexual and asexual means. Excellent accounts of the aphid life history can be found in Markovitch (1924), Real (1955), Lees (1959) Johnson and Birks (1960), Banks and Macaulay (1964), Judge (1968), Blackman (1971) and Blackman (1974).

The development of sexual morphs in aphids is influenced by a number of environmental factors, the important ones are day length, temperature and the age of the host plant. In addition internal changes in the aphid also influence the aphid's response to its environment (Dixon, 1973). Sexual forms of aphids rarely occur in the tropics under natural environmental conditions. Basu et al. (1968) reported for the first time the appearance

of the sexuales of A. craccivora from India on Tinospora cordifolia Meirs (Menispermaceae) where they colonise the undersurface of the young leaves. T. cordifolia was recorded as a new host plant for this aphid species.

In Nigeria reproduction in A. craccivora is by parthenogenesis. No sexual forms have been observed and so all established populations consist of both parthenogenic viviparous alatae and apterae (Misari, 1975).

4. (a) PEST/PLANT RELATIONSHIP

(b) PEST/DISEASE/PLANT RELATIONSHIP

The mouthparts of aphids have been remarkably adapted to pierce plant surface and suck the nutrient sap stream in the phloem sieve tube. The feeding of aphids on plants can cause a drain in nutrients from other parts of the host plant. Kennedy and Stroyan (1959) suggested that aphids can cause the leaves on which they are feeding to act as a "sink". This may cause premature senescence of the leaves from where the nutrients are being drained.

Many insects act as vectors and play a very important role in the transmission of plant pathogenic organisms. The largest number of vectors of plant viruses are among the aphids (Haramorosch, 1963). Transmission of plant viruses by aphids

has been reviewed by Smith (1958); Broadbent and Martin, (1959); Kennedy et al. (1959); Broadbent (1960); Kennedy (1960); Posnette (1960); Watson, (1960); Carter, (1961); Kennedy et al. (1962); Watson and Plumb, (1972); and Harris and Maramorosch (1977).

Aphid - borne viruses are transmitted either in a persistent, semi-persistent or non-persistent manner (Watson and Plumb, (1972). Hull and Adams, (1968) reported that they transmitted the groundnut rosette virus (GRV) by sap transmission method. However, Rosse1, (1977), working with twenty representative isolates of the groundnut rosette virus in northern Nigeria, found that the virus was not sap transmissible, either to groundnut or to various host plants he inoculated. Also contrary to Okusanya and Watson's (1966) findings, there were no local lesions on inoculated leaves of Chenopodium spp; and systemic infection did not develop when soyabean was inoculated. These recent findings led Rosse1 (1977) to conclude that the virus was strongly persistent in its manner of transmission, and therefore, unlikely to be sap transmissible. His finding that A. craccivora once infected with the virus remained infected throughout its life supported the contention that groundnut rosette virus is a persistent virus. Depending on climatic conditions, the aphid can spread the disease rapidly.

The occurrence of the groundnut rosette disease in Africa was reported by Zimmerman in 1907 (Rosse1 1977). Storey and Bottomley (1928) in Kenya and South Africa were able to transmit the virus by means of A. craccivora as a vector. In Nigeria the disease was first reported and described over fifty years ago (Rosse1, 1977).

The symptoms expressed by infected plants vary considerably. According to Storey and Ryland (1975) and Hull and Adams (1968), there are two types of symptoms expressed as the chlorotic and the green rosette. They described plants with chlorotic rosette as having a bright yellow or white colour, while those having green rosette do not possess this character. Other workers such as Klesser (1968) described three different types of symptoms. Plants that are infected early in their growth become stunted due to reduction in internode length and leaf size. Leaf margins may be rolled inwards and petioles shortened giving the growing tip a tufty appearance. But when infected late in their growth, plants may not be stunted but symptoms are expressed in new growths (Rosel, 1976). In addition according to Misari (1975) green rosetted plants form numerous shoots and the gynophores show negative geotropic response. Pods if formed are empty.

The appearance of chlorotic rosette was first reported by Storey and Ryland (1957) from East Africa. The chlorotic rosette symptom was not reported in Nigeria until recently when Rosel (1976) observed one plant with chlorotic rosette symptom at Mokwa in Niger State of Nigeria. Subbarayudu and Harkness (1980) reported the occurrence of chlorotic rosette symptoms on groundnuts in Kano and in Plateau States during the 1978 wet season. They described the symptoms as mottling of youngest

leaves, chlorosis, green vein banding, mosaic with dark green islands and distorted leaves. In addition, plants are stunted showing rosetted appearance.

5. APHID CONTROL

The methods employed in the control of virus diseases of crop plants vary according to the manner in which the virus is transmitted. Different types of insecticides have been used to control different types of virus diseases on a wide range of crops. Non-systemic insecticides extensively used in agricultural and horticultural crops to control aphid vectors of virus diseases often fail because they are applied late in the growing season when aphids have already introduced the virus into the crop. Since it is impossible to obtain a total aphid mortality, the few survivors can build up their population fast enough and spread the disease. This secondary spread can be prevented by systemic insecticides, but primary infection by virus from outside sources cannot be thus prevented (Matson and Plumb, 1977). Control of aphid transmitted virus was reviewed by Broadbent (1969). The use of granulated systemic insecticides for the control of plant virus diseases has become increasingly important (Cook et al., 1963, Patkar et al., 1969, Hassanein et al., 1971, Oeting et al., 1978). Granular phorate and dimethoate were respectively effective in controlling

potato aphid and the leaf roll virus disease of potato (Burt et al. 1960). Myzus persicae Sulz; Macrosiphum euphorbiae Thomas; Aphis nasturtii Kalt; and Aulacorthum solani Kalt. were effectively controlled with granular disulfoton at 2 lb a.i/ac. on potato (Pond, 1963). Soil application of 0.75kg a.i/ha each of phorate, disulfoton or aldicarb was recommended in Maharashtra, India for the control of the aphid; M. persicae, jassids, Amrasca biguttula biguttula (Shir). and thrips, Caliothrips indicus (Bagn.) (Harcotrips indicus) on potato grown for seed only (Awate et al. 1978). The recommended rate at planting was effective in controlling the pests until harvest. In Egypt disulfoton powder and granules proved to be the most promising effective insecticide against Aphis gossypii Glover and A. craccivora infestation on cotton (Hassanein et al. 1971). This confirmed the results of earlier workers such as De Souza et al. (1957) and Reylonds et al. (1957). The organophosphorus insecticide, schradan, gave good control of A. craccivora on groundnut for 14-21 days in pots and small plot trials in Tanzania (Evans, 1954). The spray application of the aphicide menazon was found to give good control of the groundnut aphid and consequently of the rosette disease leading to improved yield and quality in groundnuts in Uganda (Davies and Kasule, 1964

and Davies, 1975 a). The use of menazon as a seed dressing in some field did not, however, improve the degree of control achieved. In another trial, Davies (1975 b) found that menazon was the most effective insecticide overall in reducing rosette attack. Endosulfon and dimethoate and, to a lesser extent, phosphamidon were also found to be effective.

In Nigeria, until recently, little attention was given to the use of insecticides to control A. craccivora and the rosette disease it transmits. At Samaru, the use of menazon seed dressing in pot trials gave most promising results, providing excellent control of aphids for two weeks and also to some extent reducing infection by the virus (Rossel, 1977). Results of menazon applied as foliar spray in pot trials and in field observations were not as good as those obtained from the application of this aphicide as a seed dressing. Metasystox applied as foliar spray gave rather disappointing results, while pirimicarb u.l.v. formulation applied 3 weeks after sowing gave the best results in field trials conducted at Mokwa, Nigeria.

MATERIALS AND METHODS

1. TAXONOMY

Adult apterous viviparous females of the groundnut aphid raised on healthy groundnut seedlings were collected, etherised and placed, dorsal side up on a moistened white filter paper in a petri-dish. Measurements of the lengths from the middle of the head to the base of the cauda of twenty aphids were taken using a micrometre eye-piece. The latter was calibrated with a stage micrometre to give the measurements in millimetres.

Adult apterous and alate viviparous females of the groundnut aphid were transferred into a specimen tube containing lactic acid-alcohol. The procedures followed for maceration, clearing, preparation of mountant and mounting on microscope slides were those described by Eastop and van Emden (Eastop and van Emden, 1977).

Measurements of the following appendages of mounted specimens of both apterous and alate aphids were taken :

Cornicles (siphunculi);

Antennal joints III, IV and VI respectively;

Hind tibia;

Fore tibia;

Fore tarsus.

The number of rhinaria in alates were also counted. For each of the apterous and alate aphids twenty microscopic slides were prepared. For each of the above appendages the left and right appendages were measured and the mean calculated for each specimen. Similarly the number of rhinaria on the left and right 3rd antennal segments of each alate was counted and the mean calculated.

The following diagnostically important structures of the aphid were drawn using a 'Wild M - 20' microscope with drawing tube attached:

- (a) head with antennal segments I - III of both aptera and alate;
- (b) antennal segments I - VI of aptera;
- (c) apical rostral segments of aptera;
- (d) abdomina of aptera and alate;
- (e) cauda of aptera and alate;
- (f) siphunculi of aptera and alate;
- (g) forewing.

2. APHID REARING

The aphids used in this study were obtained from ground-nuts and were identified as A. craccivora before being reared in the laboratory. Both healthy and viruliferous aphids were

reared. Forty petri-dishes were used for the initial rearing. A sheet of white filter paper was placed in a petri-dish and the latter filled with Modified Houghland - Snyder Culture Solution to the brim (Hughes and Woolcock, 1965). Using a pair of forceps, ten groundnut leaflets were carefully lowered on to the surface of the nutrient solution with each leaflet having its under surface up. A humidifier, fitted with a hygostat, was used to raise the relative humidity to 50 per cent so that the nutrient solution would not evaporate quickly. If necessary more solution was added daily to maintain the level in the petri-dishes.

One adult aptera of A. craccivora was carefully placed on each groundnut leaflet using a fine, slightly moistened camel-hair brush. The petri-dishes were placed under fluorescent tubes so that the aphids received 16 hours of artificial light per day. The following morning the adults were transferred on to another set of groundnut leaflets in petri-dishes. The nymphs produced by these adults in 20 out of the first set of 40 petri-dishes were transferred on to young and healthy groundnut seedlings planted in 12 small pots. Fifty nymphs were put on each of the 12 seedlings using the camel-hair brush. These pots were then placed in an aphid-proof cage. The cage was made from wood and black fine wire

mesh with a dimension of 87 x 87 x 87 cm supported on legs 42 cm high.

The nymphs from the other 20 petri-dishes were similarly transferred on to young rosetted groundnut plants in 12 small pots. Fifty nymphs were also placed on each rosetted groundnut plant. The pots were placed in another aphid-proof cage completely isolated from the first one- The nymphs in both cages were allowed to mature.

The above procedure of aphid rearing was repeated so that adult aphids were continuously available. However, the aphids were transferred on to young succulent seedlings every fortnight so that they had continuous access to succulent foliage to feed upon. The method used to transfer the aphids on to fresh groundnut seedling was by cutting the plant part on which the aphids were with a pair of scissors and placing it on to the fresh seedlings.

3. LIFE HISTORY

(a) Nymphal Growth and Development

Twenty adult apterae of A. craccivora were selected and each was carefully placed on a groundnut leaflet in each of twenty petri-dishes arranged as under the experiment on Aphid Rearing (Fig.1). The time the adults were placed was recorded.

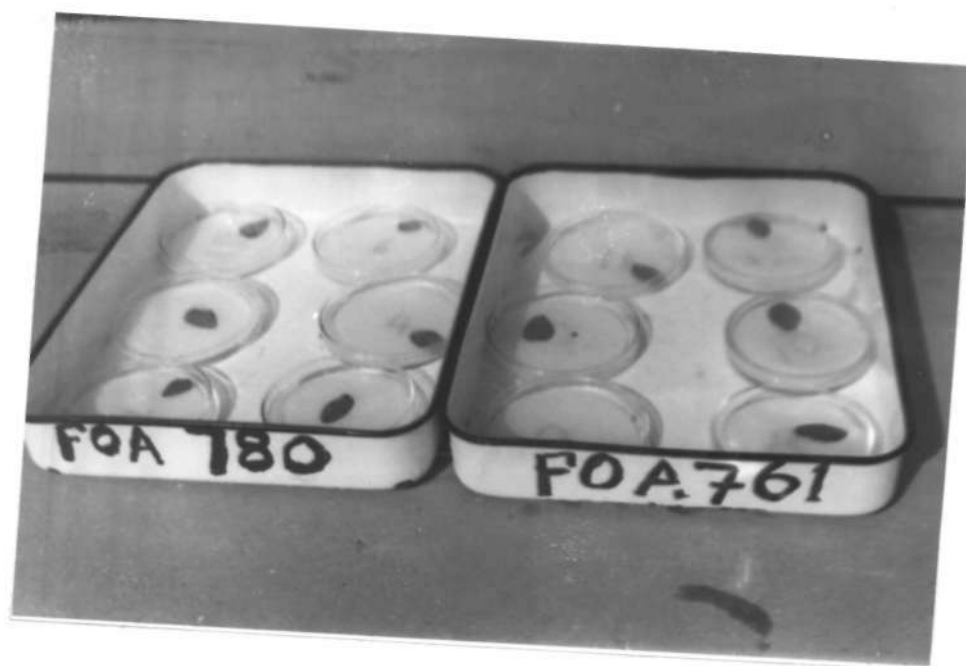


Fig. 1 Apparatus for the study of the nymphal growth and development of the groundnut aphid, A. craccivora.

These petri-dishes were numbered 1 - 20 and placed under the fluorescent lighting assembly. The petri-dishes were left over-night. The following morning the adults were carefully removed, and the time noted. From the time of removal of the adults each leaflet was examined under a binocular stereo microscope.

Larviposition and the number of exuviae observed on each leaflet were recorded. Daily counts of nymphs and exuviae as well as removal of the latter were done. As soon as a nymph became an adult, it was removed from the leaflet and the time noted. This observation was continued daily until each nymph became an adult. The same conditions as described under the experiment on aphid rearing were used in this experiment. This experiment was repeated three times.

The cumulative mean number of exuviae per aphid per day was calculated and plotted against the mean age of the nymphs. The mean age of the nymphs was estimated as the half-way time of the period during which the adults were allowed to deposit nymphs (Blackman, 1974). The mean of the total development time was calculated directly from the time of appearance of the adults on the leaflets.

(b) Fecundity

Twenty young and healthy groundnut seedlings of the same age were raised separately in twenty small plastic pots, and the latter were numbered 1 to 20. Twenty 4th instar apterous nymphs of A. craccivora were selected and one was placed in each of twenty clip-on leaf cages. Each cage was made of two perspex rings, one end of each was covered with a nylon mesh. The two rings were held together with a small curl-clip. The dimension of each cage was 1.0 cm thick x 2.0 cm diameter. The cages were clipped on each of the twenty groundnut seedlings. Only one cage was placed on a leaflet (Fig.2).

The dates when each nymph became adult and when each produced its first progeny were recorded. Nymphs produced were counted daily and carefully removed with a fine camel-hair brush. This procedure was done for each parent separately. Adults were observed for larvi-position until they died. The date when each adult died was recorded. The daily temperature and the daily percentage relative humidity were recorded using a thermohygrograph. The following records were made :

- (a) Total fecundity
- (b) Mean reproduction rate (progeny/day)
- (c) Maximum reproduction rate (progeny/day)



Fig. 2. Experimental set-up to study fecundity of aphids.

- (d) Pre-reproductive period (days)
- (e) Reproductive period (days)
- (f) Post reproductive period (days)
- (g) Longevity after adult moult (days)

The experiment was repeated using alate viviparous females and the above parameters were also determined. The temperature and percentage relative humidity over which the apterous aphids were raised ranged from 25.50°C - 35-25°C and 63.00 - 90.00 respectively. The means were 27.96°C and 83.07 respectively (Appendix 9). The temperature and percentage relative humidity range over which the alatae were raised were 26.00°C and 76.00 - 90.00, while the means were 27.27°C and 85.37 respectively (Appendix 10).

4. PEST/PLANT RELATIONSHIP AND PEST/DISEASE/PLANT RELATIONSHIP

The experiment on pest/plant relationship was done in a glasshouse. The mean temperature and mean relative humidity were 35.5°C and 65% respectively. Twenty four clay pots were filled with sterilised soil. Four seeds of groundnut were planted in each of the 24 clay pots. Superphosphate fertilizer was applied at the rate of 6.71g per pot (equivalent to 94kg per ha). After germination the seedlings were thinned to one plant per pot.

The pots were randomly separated into eight sets of three pots each. Each set of three pots represented a treatment. Ten non-viruliferous nymphs of A. craccivora per leaf were placed on each groundnut seedling as follows :

<u>Set No.</u>	<u>Time of placement of aphids</u>
1	Seedling emergence
2	One week after seedling emergence
3	Two weeks after seedling emergence
4	Three weeks after seedling emergence
5	Four weeks after seedling emergence
6	Five weeks after seedling emergence
7	Six weeks after seedling emergence
8	Control - on aphids were placed.

In the control 1g of carbofuran was applied at planting to the soil in each of the three pots to prevent aphids infesting the plants.

The effect of aphid infestation on growth was measured by observing the mean height and the number of leaflets produced at weekly interval. The plant height was measured from the soil level in the pot to the tip of the youngest leaf.

The mean plant height and the mean number of leaflets

for each treatment were calculated and the results were statistically analysed.

On pest/disease/plant relationship, observations on the different symptoms expressed by groundnut plants affected by the rosette virus were made both in the glasshouse and on the field.

5. APHID CONTROL

Preliminary trials on the control of the aphid were conducted both in the glasshouse and on the field with the following insecticides :-

(a) Carbofuran (2,3 - dihydro - 2,2 - dimethyl - 7 - benzofuranyl methylcarbamate) as Furadan 5G^(R) supplied by FMC Corporation, Agricultural Chemical Division.

(b) Disulfoton (o,o-diethyl - S-2- (ethylthio) - ethyl phosphorodithioate) as :-

i. Solvirex 5G^(R) (Frumin G 6309, G 174) used at the rates of 2.35 and 1.18kg a.i. per ha respectively.

ii. Frumin AL^(R) seed dressing dust used at the rates of 4% and 6% respectively. Both supplied by Sandoz Limited (Switzerland).

(c) Phorate (o,o-diethyl - S - (ethylthiomethyl) phosphorodithioate) as Thimet 10G^(R) used at the rates of 4.70 and 2.35kg a.i. per ha respectively. American Cyanamid Company.

(d) Pirimicarb (5,6 - dimethyl - 2 - dimethylamino - 4 - pyrimidnyl dimethylcarbamate) as :-

- i. JF 6611 40% colloidal suspension used as a 1% and 0.5% slurry for seed treatment.
- ii. JF 6612 10% colloidal suspension used as a 1% and 0.5% slurry for seed treatment.
- iii. JF 6117 1% granules used at the rates of 0.47 and 0.24 kg a.i. per ha respectively.
- iv. JF 6244 5% granules used at the rates of 2.35 and 1.18 kg a.i. per ha respectively.
- v. Pirimor 50% ^(P) dispersible powder used as a 1% and 0.5% slurry respectively.

All formulations supplied by Plant Protection Division; ICI Limited (Great Britain). The acute oral and dermal LD₅₀^S for the above four insecticides are shown in Table 1.

Two rates of application were compared for each of the granular formulations. Each of the insecticides was weighed and put in an appropriately labelled polythene bag. As a safety precaution, a gas mask and rubber hand gloves were used, and the weighing was done in a fume cupboard.

In the glasshouse experiments the granules were placed in a hole 5 cm away from the planted seeds in the pots and then

Table 1

ACUTE ORAL AND DERMAL LD₅₀'S FOR THE
INSECTICIDES USED FOR APHID CONTROL (mg/kg)

INSECTICIDE	ORAL LD ₅₀	DERMAL LD ₅₀
Carbofuran	8-14 (rat)	10,200 (rabbit)
Disulfoton	2.6 - 12.5 (rat)	20 (rat)
Phorate	2 - 4 (rat)	630 (guinea pig)
Pirimicarb	147 (rate)	-

covered with soil, while they were applied along the sides of the ridges and then covered with soil in the case of the field experiments. For disulfoton (Frumin AL), which is a seed dressing powder, 4g and 6g respectively were mixed with 100g of seed in a gourd and shaken for three minutes. The mouth of the gourd was covered to prevent the insecticide dust from escaping.

The two colloidal formulations of primicarb were applied as slurry. In both cases the formulations were diluted to 1% and 0.5%. In both cases the seeds were soaked in the slurry for one minute, allowed to dry and then planted immediately. For pirimor 50% DP a 1% suspension was prepared in which the seeds were soaked for one minute, allowed to dry and then planted immediately.

Glasshouse Experiments:

Two glasshouses were used for the screening of the insecticides to control the non-viruliferous and viruliferous aphids. Clay pots were filled with soil and four seeds of groundnut variety, Samaru 38, were planted in each pot. 6.71g single superphosphate fertilizer was applied to the soil in each pot in a hole 8cm away from the seeds. The insecticide granules were placed in a hole 5cm away from the seeds in each pot and then covered with the soil. The plants were watered

daily. There were four pots per treatment.

Field Experiments:

The screening of the insecticides to control the non-viruliferous and viruliferous aphids in the field was done on a plot 10m x 10m. It was divided into forty 2.5m long ridges spaced 1m apart. A randomized block design with four replications was used.

Superphosphate fertilizer was applied at the recommended rate of 94 kg per ha (AERLS, 1977). The granular insecticides were applied into the soil along the sides of the ridges. Four seeds of groundnut variety, Samaru 38, were planted per hole and spaced 23 cm apart along the ridges (AERLS, 1977). During the dry season the plot was watered daily. For both the glasshouse and field experiments, plants were thinned to two per stand after germination.

The placement of adult aphids on the plants was started one week after germination. Ten adult aphids were placed in each clip-on leaf cage using a moistened camel-hair brush. The cage was then clipped on to the youngest opened groundnut leaflet with the half of the cage containing the aphids placed on the underside of the leaflet (Fig.3). As the plants increased in height, it became necessary to support them with thick pieces of wire.

Observations were made 24 hours after placing the aphids on the plants. Aphids which were unable to move normally when stimulated with the camel-hair brush were classified as moribund. The numbers of normal (live), moribund and dead aphids were recorded. The percentage mortality was taken as the percentage of dead-plus-moribund. Both the moribund and dead aphids were removed from the cage and the leaflets before new ones were re-introduced to make the number up to ten. The percentage mortality was transformed to corrected mortality using Abbott's Correction Formula (Finny, 1971).

Rosetted plant count was started as soon as the symptoms appeared on any one treatment. Any plant on which the rosette symptoms appeared or on which an aphid colony developed during the course of the experiment was removed. The placement of aphids on the plants was stopped six weeks after germination.



Fig. 3. Set up of the insecticide screening experiment in the glasshouse. (Note the clip-on leaf cages in which the aphids were placed before the former were clipped on the leaflets).

RESULTS AND DISCUSSION

1. TAXONOMY

Results of the measurements of the body length, antennae, siphunculi and cauda as well as their ratios for the two morphs of the groundnut aphid are summarised in Table 2 while details are shown in Appendix 1. Results of the measurements of antennal joints III, IV and VI, hind- and fore-tibiae, fore-tarsi and the number of secondary rhinaria on segment III of the mounted specimens of the groundnut aphid are summarised in Table 3. The details are given in Appendix 2.

Aptera: The mean body length of the etherised adult aptera was found to be 1.64mm. The adult female, when alive, was observed to be shiny black. In the prepared slide both the siphunculi and cauda, as well as the dorsal part of the abdomen were black. The pigmentation of the abdomen extended laterally to enclose the lateral sclerites and to encircle the bases of the siphunculi. The antenna, siphunculus, and cauda were found to have a mean length of 1.164mm, 0.380mm and 0.281mm respectively. The antenna was 0.709 times as long as the body. The siphunculus was 0.230 times as long as the body and 1.350 times as long as the cauda. Antennal joints III, IV

and VI measured 0.321, 0.226 and 0.372mm long respectively. The hind-tibia, fore-tibia and fore-tarsus were respectively 0.955, 0.645 and 0.113mm long. Antennal joints I and II and the apex of V and the whole of VI were observed to be black whereas joints III, IV and the rest of V were pale.

Alate: The mean body length of the etherised adult alate was found to be 1.740mm. Live adults were observed to be black but not as shiny black as the apterae. In the mounted specimen each of abdominal tergites was observed to bear a black transverse bar. The lengths of the siphunculus and cauda were found to be 0.265 and 0.210mm respectively. The siphunculus was 0.183 times as long as the body while it was 1.267 times as long as the cauda. Antennal joints III, IV and VI were respectively 0.288, 0.231 and 0.414mm long. The lengths of the hind-tibia, fore-tibia and fore-tarsus were 0.883, 0.643 and 0.112 mm respectively. The mean number of secondary rhinaria on antennal segment III was 5.184. There were no secondary rhinaria on segments IV and V. The antennae were dusky to dark in colour, but segments III to base of V were observed to be paler than I, II and VI. The diagnostically important features of the aphid as shown in Figures 4 - 14.

Table 2

MEASUREMENTS OF BODY LENGTH, ANTENNA,
SIPHUNCULUS AND CAUDA AND THEIR RATIOS
FOR A. CRACCIVORA (mm)

	Aptera	Alate
Body	1.643	1.740
Antenna	1.164	-
<u>Antenna</u> <u>Body</u>	0.709	-
Siphunculus	0.380	0.255
<u>Siphunculus</u> <u>Body</u>	0.230	0.183
Cauda	0.281	0.210
<u>Siphunculus</u> <u>Cauda</u>	1.350	1.267

Table 3

MEASUREMENTS OF ANTENNAL JOINTS III, IV AND VI,
HIND-TIBIA, FORE-TIBIA AND FORE-TARSUS AND THE
NUMBER OF SECONDARY RHINARIA OF A. CRACCIVORA. (mm)

Measurement	Aptera	Alate
Antennal Joint III	0.321	0.288
Antennal Joint IV	0.225	0.231
Antennal Joint VI	0.372	0.414
Hind-tibia	0.965	0.883
Fore-tibia	0.645	0.653
Fore-tarsus	0.113	0.112
No. of rhinaria	-	5.184

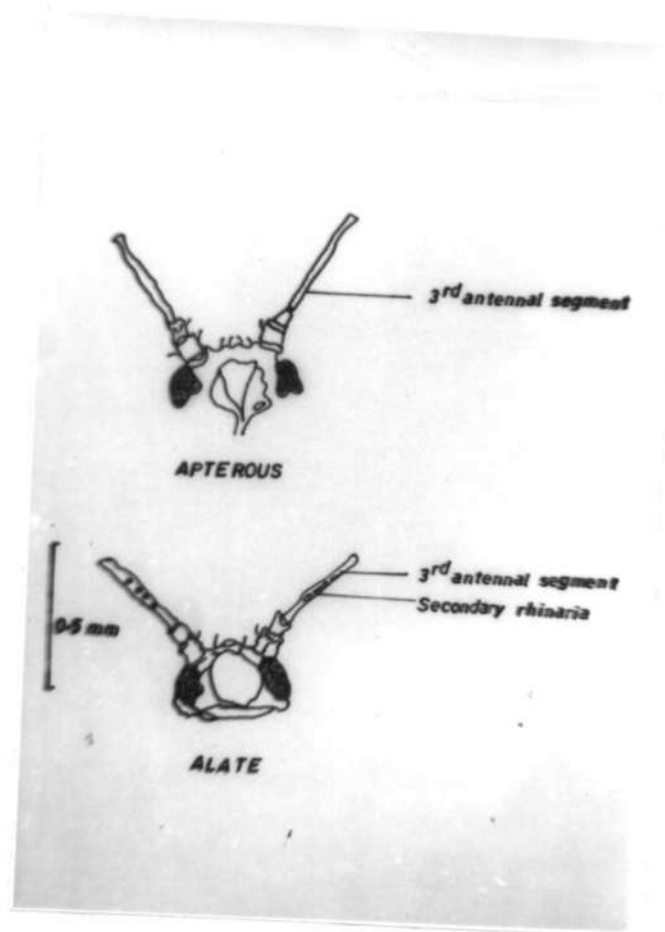


Fig. 4. Head and antenna of apterous and alate viviparous females of A. craccivora. (Note the secondary rhinaria on the 3rd antennal segment of the alate.)

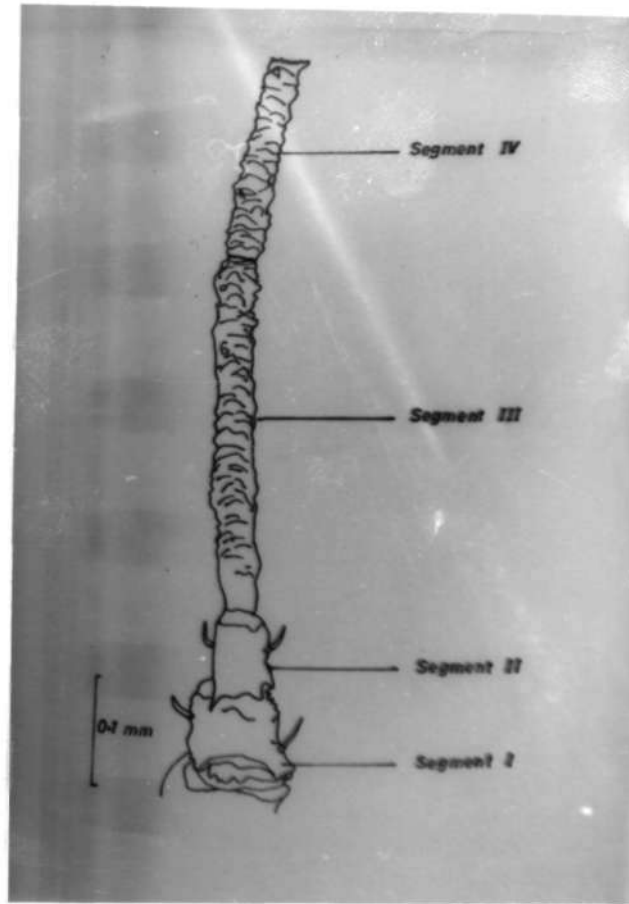


Fig. 5. Antennal segments I - IV of apterous viviparous female of *A. craccivora*.

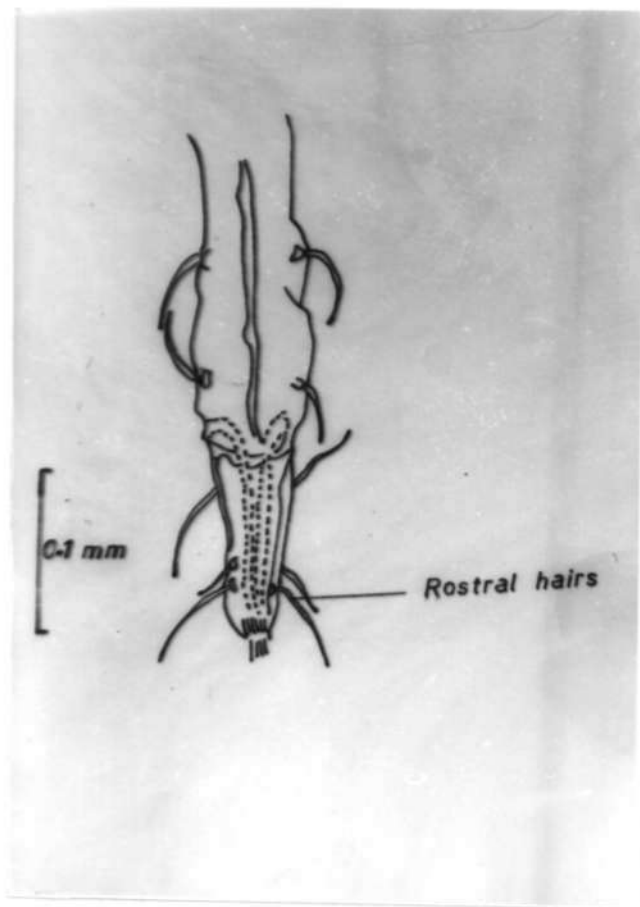


Fig. 7. Apical rostral segments of apterous viviparous female of *A. craccivora*.

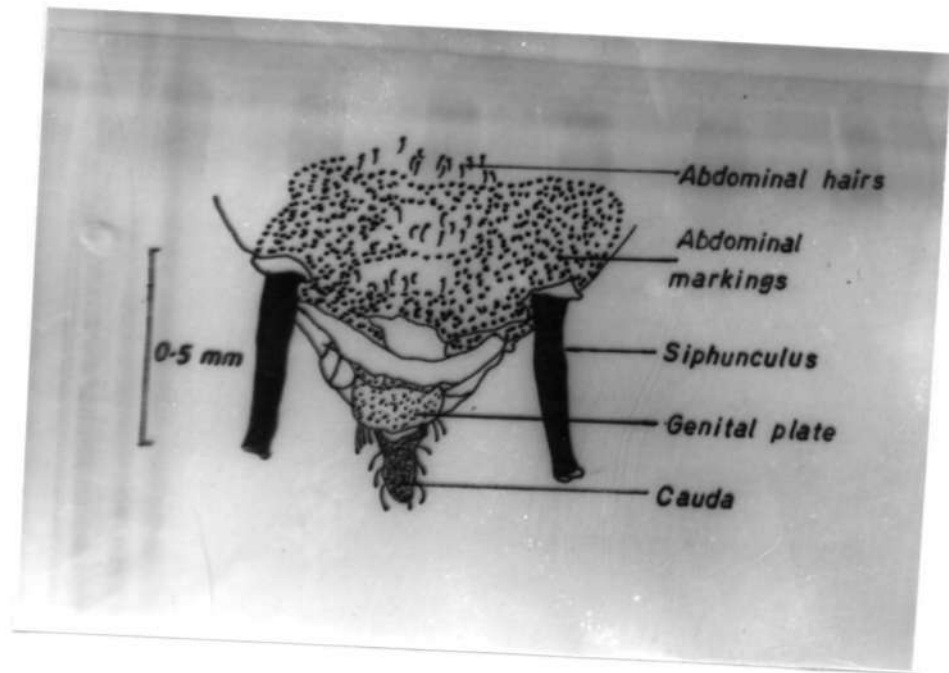


Fig. 8. Abdomina of apterous viviparous female of A. craccivora.

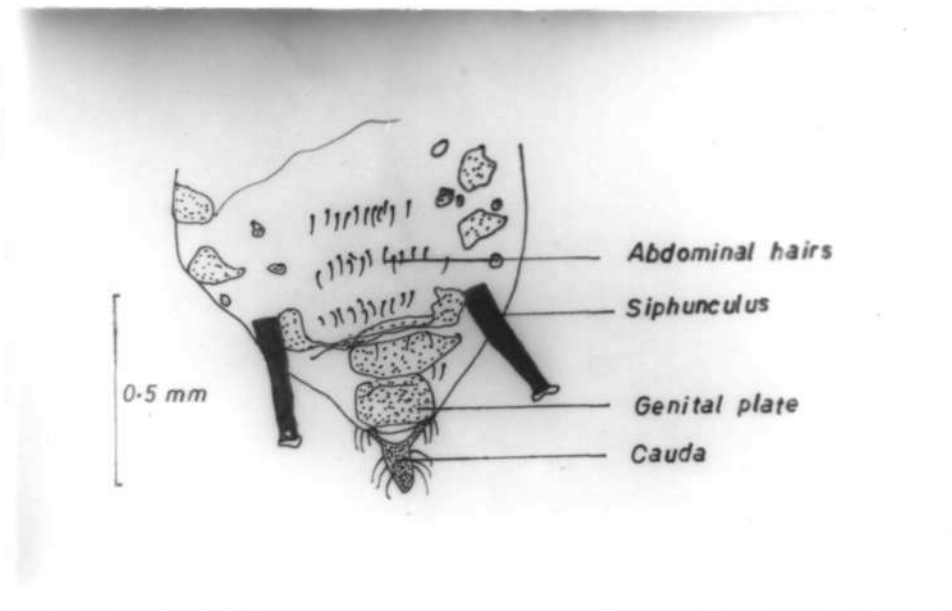


Fig. 9. Abdomina of alate viviparous female of A. craccivora

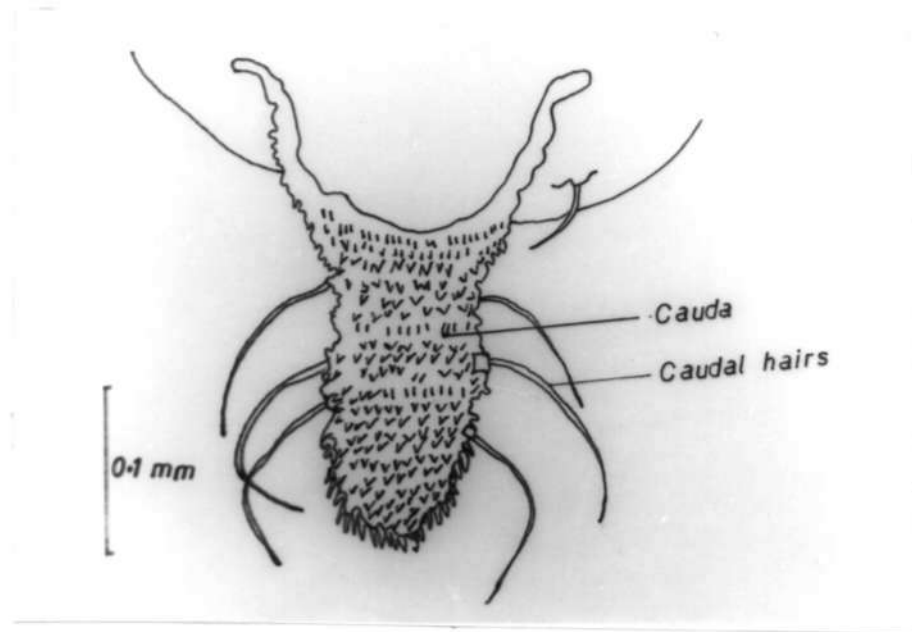


Fig. 10. Cauda of apterous viviparous female of *A. craccivora*.

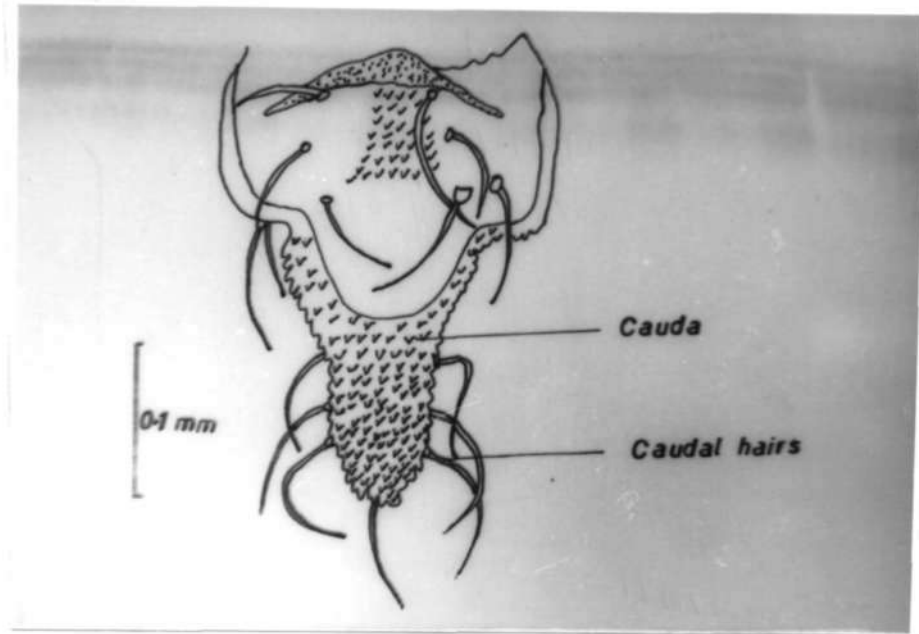


Fig. 11. Cauda of alate viviparous female of *A. craccivora*.

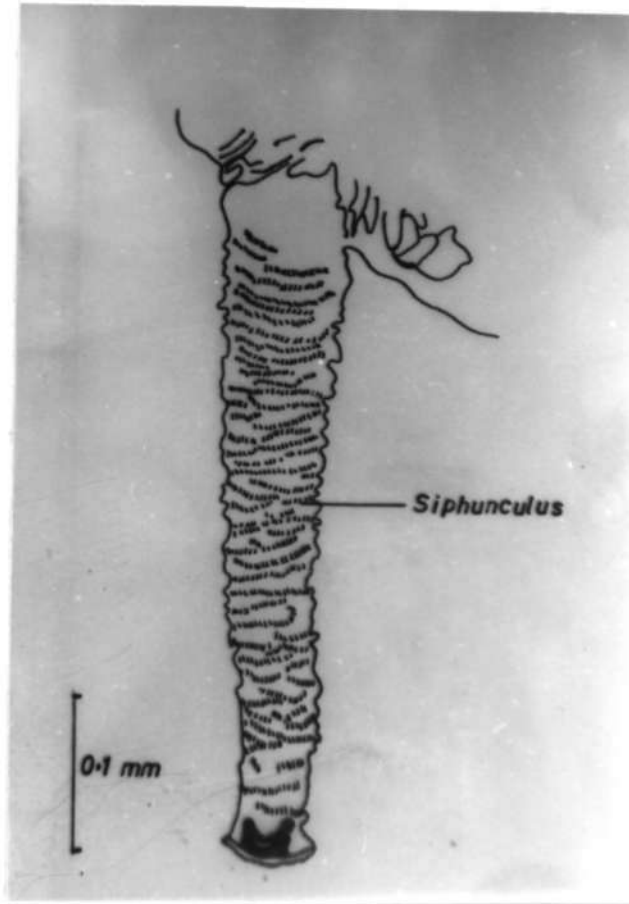


Fig. 12. Siphunculus of apterous viviparous female of A. craccivora.

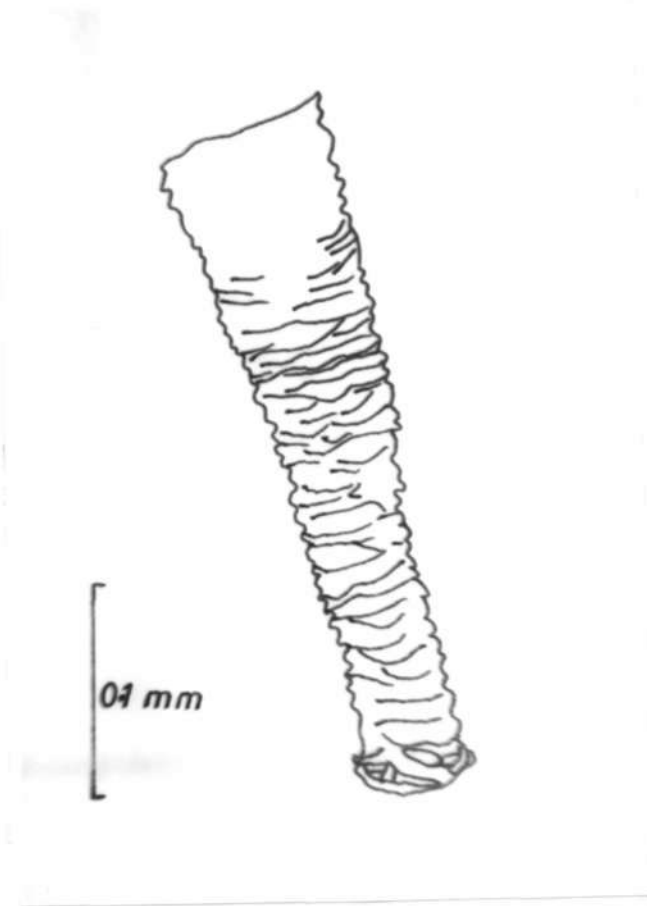


Fig. 13. Siphunculus of alate viviparous female of A. craccivora.

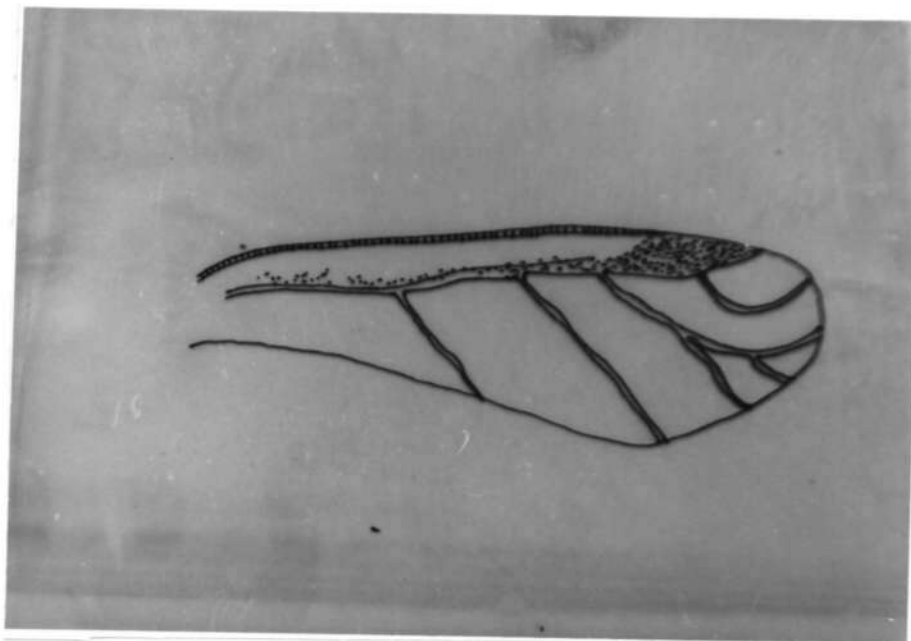


Fig. 14. Forewing of viviparous female of A. craccivora.

These results are similar to observations made by other workers on A. craccivora. Jones (1957) found the lengths as 1.696mm for the aptera only while Eastop (1961) gave a range of 1.50 - 2.00mm for both aptera and alate. Cottier (1953) gave the body length as 2.00mm and 1.90mm for the aptera and alate respectively. The minor differences reported by workers could arise from a number of factors. These included the crops and their varieties on which the aphids were raised, light, temperature and relative humidity under which the aphids were reared. These factors are known to affect the development of the aphids resulting in the differences in size. Jones (1957), working with two clones of A. craccivora, one from Nigeria and the other from Kenya, found some differences in the lengths of some appendages of the same clone raised on groundnut and V. faba respectively.

The lengths of the siphunculus, hind-tibia, fore-tibia and fore-tarsus are comparable to those obtained by Jones (1957) (Tables 4 and 5). Similarly the lengths of the antennal joints III, IV and VI are comparable to those reported by Cottier (1953) and Jones (1957). The ratios of the various appendages obtained in this study agreed with those obtained by Cottier (1953) and Eastop (1961)(Tables 6 and 7).

Table 4

COMPARISON OF THE MEASUREMENTS OF VARIOUS APPENDAGES
OF APTEROUS VIVIPAROUS FEMALE OF *A. CRACCIVORA* OBTAINED
IN DIFFERENT STUDIES (mm)

Author	Antennal Joint			Tibia		Fore Tarsus	Siphunculus
	III	IV	VI	Hind	Fore		
Cottier (1953)	0.300	0.210	0.371	-	-	-	0.380
Jones (1967)	0.272	0.175	0.334	0.908	0.642*	0.112*	0.336
Present Study	0.321	0.226	0.372	0.965	0.645	0.113	0.380

* Aphids were raised on V. faba

Table 5

COMPARISON OF THE MEASUREMENTS OF VARIOUS
APPENDAGES OF ALATE VIVIPAROUS FEMALE OF
A. CRACCIVORA OBTAINED IN DIFFERENT STUDIES (mm)

Author	Antennal Joint			Tibia		Fore cursus	Sipun- culus	No. of Secondary rhinaria
	III	IV	VI	Hind	Fore			
Cottier (1953)	0.280	0.220	0.390	-	-	-	0.300	3-7
Jones (1957)	0.267	0.201	0.358	0.860	0.682*	0.112*	0.222	6.090
Present Study	0.288	0.231	0.414	0.833	0.653	0.112	0.265	5.184

*Aphids were raised on V. faba

Table 6

COMPARISON OF THE RATIOS OF VARIOUS APPENDAGES
AND BODY LENGTHS OF APTEROUS VIVIPAROUS FEMALE
OF A. CRACCIVORA OBTAINED IN DIFFERENT STUDIES

Ratio	Cottier (1953)	Eastop (1961)	Present Study
$\frac{\text{Antenna}}{\text{Body}}$	0.600	0.667	0.709
$\frac{\text{Siphunculus}}{\text{Body}}$	0.190	0.143 - 0.250	0.230
$\frac{\text{Siphunculus}}{\text{Cauda}}$	1.810	1.400 - 1.800	1.350

Table 7

COMPARISON OF THE RATIOS OF VARIOUS APPENDAGES
AND BODY LENGTHS OF ALATE VIVIPAROUS FEMALE OF
A. CRACCIVORA OBTAINED IN DIFFERENT STUDIES

Ratio	Cottier (1953)	Eastop (1961)	Present Study
<u>Siphunculus</u> Body	0.158	0.111 - 0.182	0.183
<u>Siphunculus</u> Cauda	1.580	1.330 - 1.750	1.267

2. LIFE HISTORY

(a) Nymphal Growth and Development

A summary of the cumulative mean of exuviae per nymph for each of the three experiments is shown in Table 8. Detailed results are shown in Appendices 3 - 5. Table 9 shows the mean daily temperature ($^{\circ}\text{C}$) and the mean percentage relative humidity over which the experiment was performed.

An almost linear relationship between the mean number of exuviae produced daily and the mean age of the nymphs was observed with a regression co-efficient (r) = 0.9987 (Fig.15). The complete regression analysis is shown in Appendix 6.

From the regression equation ($y = 0.55 + 0.025 x$) the mean duration of instars I - V is calculated and shown in Table 10. The average instar length is 40 hours and the number of instars is five. The mean of total development time from birth to maturity on the groundnut leaflet was 165 hours.

Table 8

SUMMARY OF THE CUMULATIVE MEAN OF EXUVIAE
PER NYMPH OF ACRACCIORNA FOR THREE EXPERIMENTS

Time	Cumulative Mean of Exuviae per Nymph			Mean
	Expt. I	Expt. II	Expt. III	
33	0.43	0.02	0.28	0.24
57	1.17	0.58	0.96	0.89
81	1.79	1.02	1.53	1.45
105	2.35	1.70	2.28	2.11
129	2.86	2.15	2.92	2.64
153	3.65	2.41	3.53	3.20
177	4.00	3.35	4.17	3.84
201	4.38	-	4.92	4.65

Table 9

MEAN DAILY TEMPERATURE ($^{\circ}\text{C}$) AND MEAN DAILY (%)
RELATIVE HUMIDITY OF NYMPHAL GROWTH AND DEVELOPMENT OF A. CRACCIVORA

Time (hours)	Mean Temp. ($^{\circ}\text{C}$)	Daily % rh.
33	27.75	85.25
57	27.00	83.50
81	26.75	90.00
105	27.20	87.00
129	27.20	86.50
153	31.45	90.00
177	27.95	81.50
201	27.50	89.50
Mean	27.85	86.66

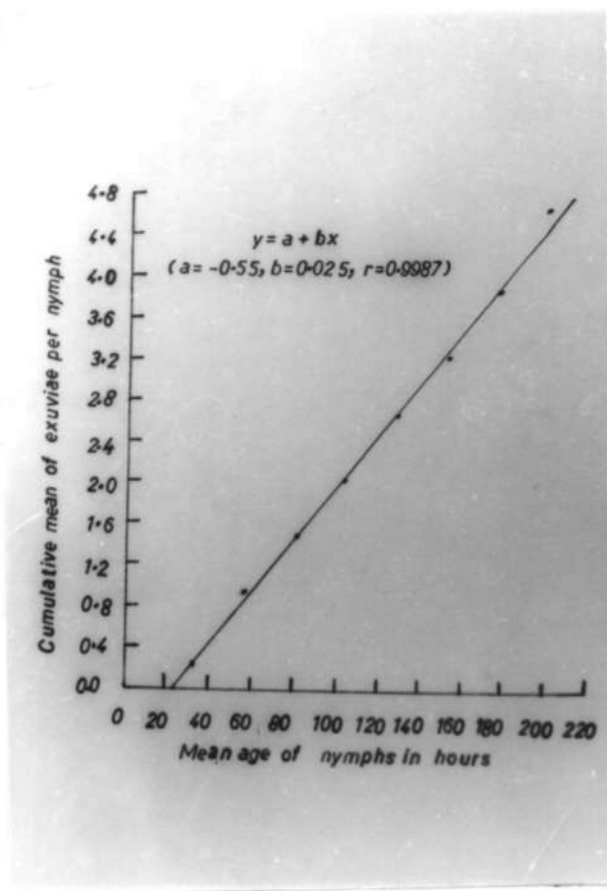


Fig. 15. Graphical representation of nymphal development of A. craccivora based on the mean numbers of exuviae produced each day.

Table 10

MEAN DURATION (HOURS) OF INSTARS
I - V OF A. CRACCIVORA

INSTAR	DURATION (HOURS)
I	62
II	102
III	142
IV	182
V	222

The fact that an almost linear relationship of the nymphal development, based on the mean numbers of exuviae produced daily, was obtained indicated that the instars were all about equal in length (40 hours). The straight line did not pass through the origin as indicated by the value of 'a' (-0.55) from the regression equation. Hence the first instar took longer time (62 hours) to develop than the subsequent ones. This confirmed the results obtained by Radke et al. (1973) who found that in general the first instar of Aphis craccivora was the longest.

(b) Fecundity

The reproductive life of apterous and alate viviparous females of A. craccivora is compared in Table 11 and Fig. 16. Appendices 7 and 8 show the detailed results of the fecundity of the two morphs respectively. The apterous aphid produced a mean total of 54.40 offspring while the alate produced a mean total of 22.95 offspring in 15.50 and 9.25 days respectively. Thus 31.45 more offspring were produced by the aptera than by the alate.

The aptera began reproducing within 0.95 days or 22.80 hours of the adult moult whereas the alate did not start reproducing until 2.10 days after the adult moult. Longevity of the apterous and alate aphids after the adult moult was 17.85 and 11.65 days respectively.

The mean reproduction rate of the aptera and alate were 2.47 and 1.35 progeny per day respectively. Moreover the aptera had a higher maximum reproduction rate of 6.00 progeny per day than the alate which had only 2.90.

Table 11

COMPARISON OF THE REPRODUCTIVE LIFE OF APTEROUS
AND ALATE VIVIPAROUS FEMALES OF A. CRACCIVORA.

	Aptera	Alate
Total Fecundity	54.40	22.95
Mean reproduction rate (progeny/day)	2.47	1.35
Maximum reproduction rate (progeny/day)	6.00	2.90
Pre-reproductive period (days)	0.95	2.10
Reproductive period (days)	15.50	9.25
Post-reproductive period (days)	1.40	0.30
Longevity after adult moult (days)	17.85	11.65

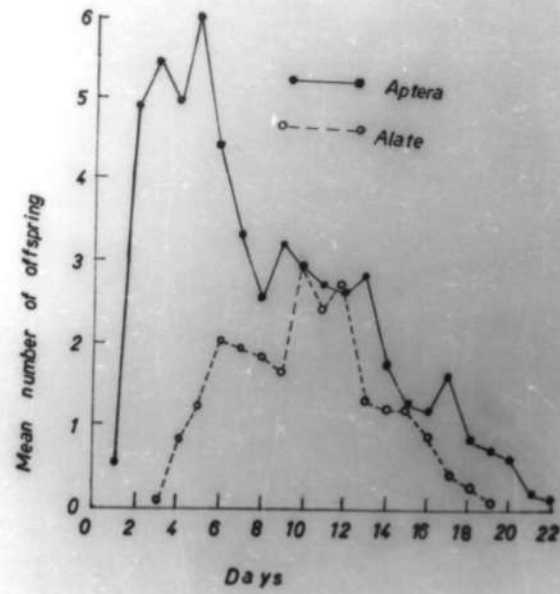


Fig. 16. Fecundity (number of offspring produced per day) of apterous and alate viviparous females of A. craccivora.

The reproductive period of the aptera was longer than that of the alate. This was in contrast to the findings of Elliot and Mc Donald (1976) who found that apterous A. craccivora produced more offspring in a shorter time than alatae. In their experiment the aphids were reared on mature leaves of broad bean Vicia faba L. (cv. Coles Dwarf) at a temperature of between 21°C and 31°C. In the present study the aphids were reared on groundnut at a temperature range of 25.75°C and 31.92°C.

Alatae did not settle down to feed and reproduce until 2.10 days after the adult moult. This is similar to the results of Elliot and Mc Donald (1976). Also in their work they found that alatae lived longer than the apterae, whereas in this work apterae lived longer than the alatae. Similarly the maximum reproduction rate (progeny/day) was higher for the apterae than the alatae.

3. PEST/PLANT RELATIONSHIP AND PEST/DISEASE/PLANT RELATIONSHIP

The mean plant height per week and the mean increase in plant height per week in the different treatments are shown in Table 12. Table 13 indicates both the mean number of leaflets per week and the mean increase in the number of leaflets per week. Statistical analysis of the results showed that there

were no significant differences in plant height and number of leaves respectively between treatments, weeks and replications (Appendices 11 and 12).

The chlorotic and green rosette symptoms were seen on plants in the field and were also transmissible under controlled conditions. However, there were more groundnut plants with the green rosette symptoms than the chlorotic in the field. Figures 17 - 21 show the different rosette symptoms as seen in the field and under glasshouse conditions.

Table 12

MEAN PLANT HEIGHT PER WEEK AND MEAN INCREASE IN
PLANT HEIGHT PER WEEK (cm.)

Time of placement of aphids	Mean Plant height per week (cm.)						Mean Increase in Plant Height per week (cm.)					
	1	2	3	4	5	6	1	2	3	4	5	6
Seedling emergence	6.17	8.87	12.50	14.23	16.60	18.17	-	2.70	3.63	1.73	2.37	1.57
One week after seedling emergence	6.93	10.90	12.83	14.73	16.97	18.27	-	3.97	1.93	1.99	2.24	1.30
Two weeks after seedling emergence	6.63	11.50	13.17	14.43	16.00	18.17	-	4.87	1.67	1.26	1.54	2.17
Three weeks after seedling emergence	5.67	11.67	13.93	14.43	16.97	19.00	-	6.00	2.26	0.50	2.54	2.03
Four weeks after seedling emergence	6.00	10.47	12.27	12.90	13.90	16.50	-	4.47	1.80	0.63	1.00	2.60
Five weeks after seedling emergence	5.30	8.17	9.77	11.33	13.33	15.33	-	2.87	1.60	1.56	2.00	2.00
Six weeks after seedling emergence	6.93	12.53	15.17	15.77	16.60	18.10	-	5.60	2.64	0.60	0.83	1.50
Control - no aphids were placed.	7.00	13.30	15.93	17.17	18.50	19.50	-	6.30	2.63	1.24	1.33	1.00

S.E.d 0.68 1.02 1.16 1.41 1.61 1.84
 N.S. N.S. N.S. N.S. N.S. N.S.

Table 13

MEAN NUMBER OF LEAFLETS PER WEEK AND MEAN INCREASE
IN NUMBER OF LEAFLETS PER WEEK

Time of placement of aphids	Mean number of leaflets per week						Mean Increase in number of leaflets per week					
	1	2	3	4	5	6	1	2	3	4	5	6
Seedling emergence	6.00	9.67	11.33	12.67	14.33	18.00	-	3.67	1.66	1.34	1.66	3.67
One week after seedling emergence	6.67	12.00	14.00	16.33	20.00	19.67	-	5.33	2.00	2.33	3.67	0.33
Two weeks after seedling emergence	6.00	12.00	15.33	17.67	18.33	32.33	-	6.00	3.33	2.34	0.66	4.00
Three weeks after seedling emergence	5.00	10.00	13.00	16.00	18.67	22.00	-	5.00	3.00	3.00	2.67	3.33
Four weeks after seedling emergence	5.67	9.33	13.00	16.00	20.67	21.33	-	3.66	3.67	3.00	4.67	0.66
Five weeks after seedling emergence	4.00	7.33	10.00	12.33	14.67	16.67	-	3.33	2.67	2.33	2.34	2.00
Six weeks after seedling emergence	5.67	10.33	13.67	16.67	20.67	20.33	-	4.66	3.34	3.00	4.00	0.34
Control - no aphids were placed	6.67	13.67	19.00	21.00	27.00	29.00	-	7.00	5.33	2.00	6.00	2.00

S.E.d 0.87 1.36 1.56 2.05 3.30 3.50
 N.S. N.S. N.S. N.S. N.S. N.S.



Fig. 17. A field of groundnut crop heavily infested with both the green and chlorotic rosette viruses.

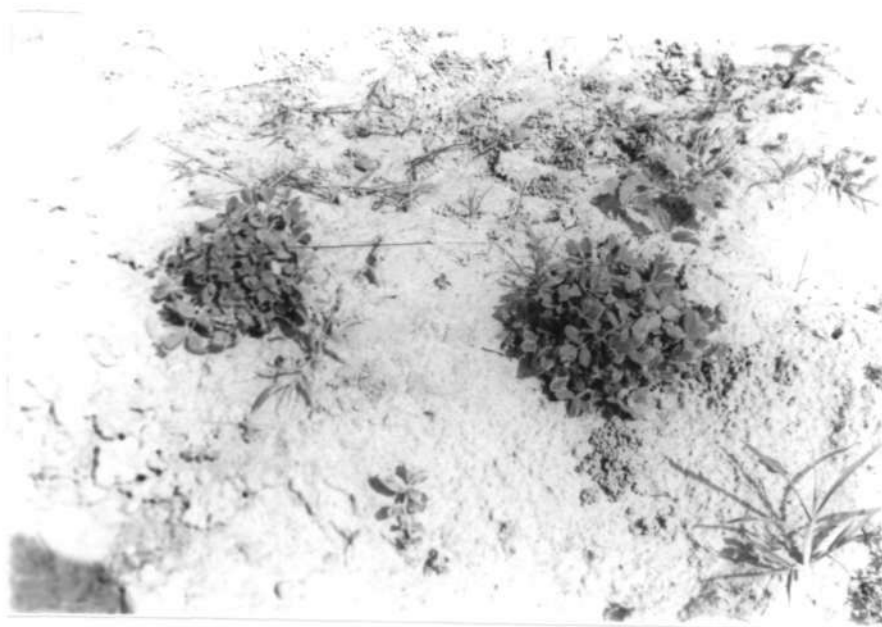


Fig. 18. Green and chlorotic rosette on groundnut plants. On the left is a plant with typical green rosette symptoms, while on the right is a plant showing chlorotic rosette symptoms. (Note the distortion of leaves in both cases, the mottling of leaves in the plant on the right and the stunted growth of the one on the left.)



Fig. 19. Comparison of a healthy groundnut plant with those affected by the green and chlorotic rosette viruses. (Note the more stunted growth of the plant affected by the green rosette virus).

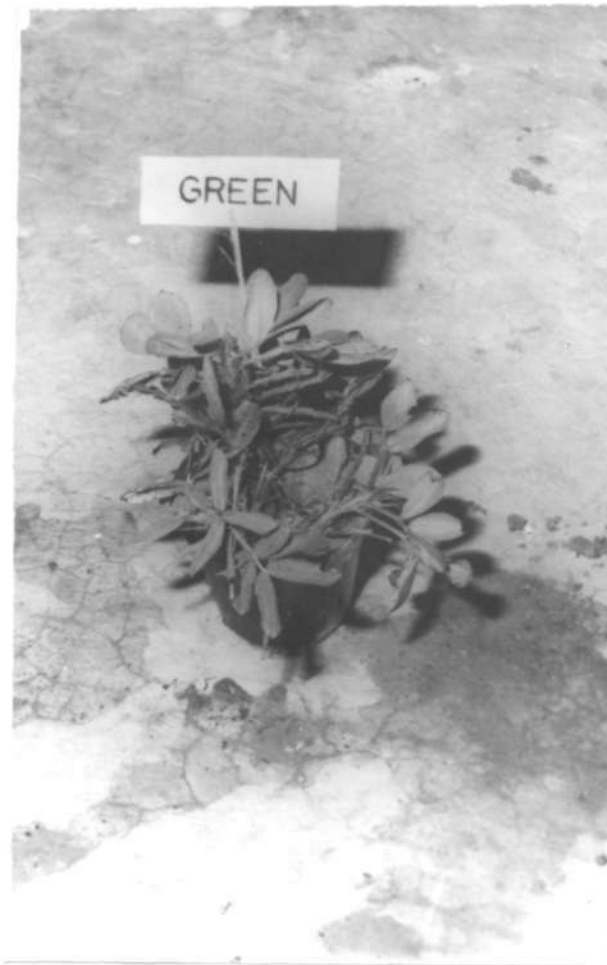


Fig. 20. Groundnut plant in pot showing the green rosette symptoms. (Note the stunting of the plant and small leaflets).



Fig. 21. Groundnut plant in pot showing chlorotic rosette symptoms. (Note the mottling of youngest leaves, chlorosis and vein banding mosaic).

The differences obtained in the two growth characteristics are insignificant. It is apparent that the aphid population pressure on the plants was too low to cause significant differences in plant height and number of leaves between treatments. Therefore feeding of ten aphids per leaf had no effect on the growth of the plants. It was observed during the course of the experiment that many of the aphids either developed wings and migrated or died as the plants became older. Yayock (1977), studying the effect of rosette disease on growth characteristics of groundnut in Nigeria, found significant differences in plant height, number of leaflets and dry matter accumulation, among other growth characteristics.

The chlorotic and green rosette symptoms observed conformed to those described by earlier workers such as Storey and Rayland (1957), Hull and Adams (1968), Klesser (1968), Misari (1975) and Rossel (1975).

4. APHID CONTROL

The mean percentage mortalities of the non-viruliferous aphids up to 35 days after treatment with the various insecticides are shown in Tables 14 and 15 for the glasshouse and field experiments respectively. The data obtained on observations with rosetted plants are summarized in Tables 16 and 17.

Two colloidal formulations of pirimicarb (JF 6611 1% and 0.5% and JF 6612 1% and 0.5% slurry) were eliminated from the experiments as aphid colonies developed on plants treated with these insecticides after one week of aphid introduction.

At both dosages the mean percentage mortalities of the non-viruliferous aphids were more than 90 in all treatments except the control (Table 14 and 15). One hundred per cent mean mortality was observed in the case of pirimicarb granules (JF 6244) at 1g per pot and disulfoton seed dressing powder (Frumin A1) at 4g per 100kg seeds (Table 14).

In the glasshouse experiment only phorate granules (Thimet 10G) at 0.5g per pot was able to protect the treated plants from the rosette disease. All the four plants treated with granular disulfoton (Solvirex 5G) and those treated with granular carbofuran (Furadan 5G) and dispersible powder of pirimicarb (Pirimor 50 DP) as well as those in the control developed the rosette symptoms. In the case of pirimicarb granules (JF 6244) only two out of the four treated plants showed the symptoms of the disease, whereas three developed the symptoms in the case of disulfoton seed dressing powder (Frumin AL) and granular pirimicarb (JF 6117) treated plants (Table 16). The number of days it took the rosette symptoms to appear in the plants treated with the

Table 14

MEAN PER CENT MORTALITY OF NON-VIRULIFEROUS
A. CRACCIVORA IN THE GLASSHOUSE EXPERIMENT

Chemical	Mean % mortality of aphids up to 35 days after treatment	
	1.00g/pot	0.50g/pot
Solvirex 5G ^(R)	97.79	94.76
Carbofuran 5G	99.07	99.05
Thimet 10G ^(R)	96.99	99.90
Pirimicarb JF 6244	100.00	99.86
Pirimicarb JF 6117	96.72	98.21
Frumin AL ^{1(R)}	99.81	100.00
Control	20.00	52.63

1 Used as a seed dressing at the rates of 6g/100kg seeds and
4g/100kg seeds respectively.

Table 15

MEAN PERCENT MORTALITY OF NON-VIRULIFEROUS
A. CRACCIVORA IN THE FIELD EXPERIMENT

Chemical	Mean % mortality of aphids up to 35 days after treatment	
	1.00g/stand	0.50g/stand
Solvirex 50 (R)	96.36	95.50
Carbofuran 50	99.21	94.50
Thimet 10G (R)	96.51	92.00
Pirimicarb 5F 6244	94.57	96.14
Pirimicarb 5F 6117	99.36	92.79
Pirimor 50 DP ¹ (R)	-	92.21
Fruin AL SD ² (R)	99.43	98.36
Control	0.42	21.43

¹ used as a 0.5% slurry.

² used as a seed dressing at the rates of 6g/100kg seeds and 4g/100kg seeds respectively.

Table 16

NUMBER OF ROSETTED PLANTS AND DAY TO THE APPEARANCE
OF THE ROSETTE SYMPTOM (D.A.R.S.) IN THE GLASSHOUSE
EXPERIMENT

Chemical	Plant No.	Disease Score		D.A.R.S.	
		0.50g/pot	1.00g/pot	0.50g/pot	1.00g/pot
Solivirex 5G (R)	1	1	1	24	25
	2	1	1	28	26
	3	1	1	23	20
	4	1	0	28	-
Carbofuran 5G	1	1	1	25	20
	2	1	0	28	-
	3	1	0	24	0
	4	1	1	24	24
Thimet 10G (R)	1	0	0	-	-
	2	0	1	-	24
	3	0	1	-	24
	4	0	0	-	-
Pirimicarb 5G (JF 6244)	1	1	1	24	15
	2	0	0	-	-
	3	0	1	-	20
	4	1	0	25	-
Pirimicarb 1G (JF 6117)	1	1	1	17	19
	2	0	1	-	19
	3	1	1	27	23
	4	1	0	35	-

Table 16 (cont'd)

Pirimor 50 DP ¹ (R)	1	1	0	16	-
	2	1	1	24	19
	3	1	1	21	24
	4	1	0	15	-
Frumin ALSDB ² (R) (50% w/w)	1	1	1	24	20
	2	0	1	-	19
	3	1	0	33	-
	4	1	0	31	-
Control	1	1	1	11	11
	2	1	1	10	14
	3	1	1	11	11
	4	1	1	13	13

¹ used as a 1% and 0.5% slurry.

² Used at the rates of 4g/100kg seeds and 6g/100kg seeds respectively.

Table 17

NUMBER OF ROSETTED PLANTS AND DAYS TO THE APPEARANCE
OF THE ROSETTE SYMPTOM (D.A.R.S.) IN THE FIELD
EXPERIMENT

Chemical	Plant No.	Disease Score		D.A.R.S.	
		0.50g/stand	1.00g/stand	0.50g/stand	1.00g/stand
Solvirex 5G ^(R)	1	1	1	22	23
	2	1	1	31	33
	3	1	1	17	23
	4	0	0	-	-
Carbofuran 5G	1	1	1	28	24
	2	0	0	-	-
	3	1	0	23	-
	4	1	1	16	25
Thimet 10G ^(R)	1	1	1	32	18
	2	0	0	-	-
	3	0	0	-	-
	4	NO GERMINATION	0	NO GERMINATION	24
Pirimicarb 5G (JF 6244)	1	1	1	29	18
	2	0	0	-	-
	3	1	1	34	34
	4	NO GERMINATION	1	NO GERMINATION	32
Pirimicarb 1G (JF 6117)	1	1	1	26	28
	2	0	0	-	-
	3	1	1	27	18
	4	0	0	-	-

Table 17 (cont'd)

Pirimor 50 DP ¹ (R)	1	1	1	18	24
	2	1	0	21	-
	3	1	1	19	29
	4	1	0	20	-
Frumin AL SD ² (R)	1	1	0	20	-
	2	0	1	-	21
	3	0	1	-	31
	4	1	0	32	-
Control	1	1	1	7	12
	2	1	1	7	13
	3	1	1	7	13
	4	1	1	10	13

¹ used as a 1% and 0.5% slurry.

² used at the rates of 4g/100kg seeds and 6g/100kg seeds respectively.

various insecticides ranged from 15 to 35, while it took only 10 to 13 days in the control.

At the rate of 1g per pot or at 1% slurry, three out of the four plants treated with granular disulfoton (Solvirex 5G) showed the rosette symptom. This was the same in the case of pirimicarb granules (JF 6117). Only two out of the four plants treated with 1g per pot or 1% slurry of the other insecticides developed the disease symptom. All the plants in the control expressed the rosette symptoms between 11 and 14 days after inoculation with the viruliferous aphids.

The results of the field experiment (Table 17) showed that at 0.5g per stand or 0.5% slurry, all the four plants treated with pirimicarb dispersible powder (Pirimor 50 DP) and those in the control expressed the disease symptoms in 18 to 21 days and 7 to 10 days for pirimor dispersible powder (Pirimor 50 DP) and the control respectively. In the case of granular phorate (Thimet 10G) treated plants, only one out of the three plants became rosetted after 32 days. For pirimicarb granules (JF 6244) treated plants, two out of the three plants became rosetted. Only one plant out of four expressed the rosette symptom in the case of granular disulfoton (Solvirex 5G) and carbofuran granules (Furadan 5G) treated plants.

For granular pirimicarb (JF 6117) and disulfoton powder (Frumin AL) treated plants, two out of the four treated plants showed the rosette symptom in each case. The number of days it took for the rosette symptom to appear in the different treatments ranged between 16 to 34 days except in the control which took only 7 to 10 days.

At treatment rate of 1g per stand only one out of the four granular phorate (Thimet 10G) treated plants developed the rosette symptoms in 18 days. While three out of the four plants treated with granular disulfoton (Solvirex 5G) and three out of the four treated with pirimicarb granules (JF 6244) developed the rosette symptoms, only one out of the four granular phorate (Thimet 10G) treated plants showed the rosette symptom. In the cases of carbofuran granules (Furadan 5G) pirimicarb granules (JF 6117) pirimicarb dispersible powder (Pirimor 50 DP) and disulfoton seed dressing powder (Frumin AL) treated plants two out of the four plants in each case developed the disease symptoms. All the four plants in the control showed the rosette symptoms in 12 to 13 days after inoculation.

The insecticides used in these experiments were preliminarily applied at the rates recommended by their manufacturers. All except pirimicarb JF 6611 and JF 6612 each at 1% and 0.5% slurry seed treatment, gave effective control of the aphids up to 35 days

after treatment. This trial was a follow-up of the work done at the Institute for Agricultural Research, Samaru, Zaria, Nigeria in 1977 to 1978 (IAR, 1978). The work indicated that there was a possibility of controlling both the aphids and the rosette disease. The best results were obtained from disulfoton used both as a seed dressing (Frumin AL) and as granules (Solvirex), (IAR, 1978). However, in the present work pirimicarb JF 6117 and Frumin AL gave the best results in terms of aphid control. In terms of rosette control Thimet 10G at 0.5g per pot gave the best results while carbofuran 5G, Thimet 10G, pirimicarb 5G, Pirimor 50 DP and Frumin AL gave the best results at 1.0g per pot.

In the case of aphid and rosette control in the field, the best results were obtained from Thimet 10G, pirimicarb JF 6117 and Frumin AL at 0.5g per stand. At 1.0g per stand Thimet 10G gave the best results followed by carbofuran 5G, Pirimor 50 DP and Frumin AL.

Although these insecticides proved effective, all have very low oral LD₅₀ values except pirimicarb which is a selective aphicide. It is not therefore safe to suggest the use of these toxic chemicals by the unskilled groundnut farmers. It is suggested that further trials be conducted giving special considera-

tion to pirimicarb granules due to its relatively higher oral LD₅₀ value and specific aphicidal action.

The possibility of using carbofuran granules in large scale mechanised farms as well as on Farm Centres could also be investigated, as this formulation has the higher dermal LD₅₀ value than the other insecticides tested. However, the necessary safety precautions should be taken in its use.

Control of foliar insects with systemic insecticides is not the final answer, since there are soil insect pests of groundnuts. This aspect also needs further investigations with a view of evolving recommendations for control of soil pests of groundnuts. This will go along way in increasing groundnut yields both in quality and in quantity.

C O N C L U S I O N

Aphis craccivora is an important pest of groundnuts for two reasons: (i) direct injury caused by aphids feeding of plant sap, young plants are specially very susceptible and (ii) transmission and spread of the groundnut rosette virus. the cause of 1975 epiphytotic which severely affected 0.6 million ha of groundnuts resulting in an estimated yield loss of 500,000 tons worth about one hundred million Naira.

Though this insect is recognised as potentially the most important pest of groundnuts in northern Nigeria, little is known about the bionomics of this pest and no work has been done toward establishing its economic injury level.

Groundnuts are important to the economy of Nigeria and the Federal Government through the Nigerian Groundnut Board and the States Ministry of Agriculture, is now engaged in a massive effort known as "the Groundnut Rehabilitation Programme." One of the main problems is the restoration of the confidence of the farmers in the groundnut crop. To achieve this the risks associated with the crop must be reduced. One important risk is the aphid, A. craccivora.

The present study is a modest effort to take a closer look at the different aspects of the biology and taxonomy of the aphid in Nigeria. The results of investigations on pest/damage relationship.

S U M M A R Y

The groundnut aphid, Aphis craccivora Koch. (Hemiptera: Aphididae) is the most important pest of groundnuts in Nigeria. It sucks the plant juices and transmits the groundnut rosette virus (GRV). The work reported here is a preliminary study on the taxonomy and bionomics of the insect. Possibilities of controlling the insect and the disease it transmits with insecticides applied as seed dressing and as soil granules have also been investigated.

The adult apterous female has a shiny black appearance, the siphunculus, cauda and the dorsal part of the abdomen being black. The abdominal pigmentation extends laterally to enclose the lateral sclerites and to encircle the bases of the siphunculi. The mean body length of the adult aptera was found to be 1.64mm. The antenna, siphunculus and cauda had average lengths of 1.16, 0.38 and 0.28mm respectively. The antenna was 0.71 times as long as the body. The siphunculus was 0.23 times as long as the body and 1.35 times as long as the cauda. Antennal joints III, IV and VI were 0.32, 0.23 and 0.37mm long respectively. The mean length of the hind-tibia, fore-tibia and fore-tarsus was 0.97, 0.65 and 0.11mm respectively. The adult alate female was black, but not as shiny black as the adult aptera. Each of its abdominal

relationship are inconclusive and much more work is required.

The experiments on control have indicated that seed dressing and granular formulations of insecticides can be used to protect the plants from aphid attack and the rosette disease it transmits for the first six weeks of crop life, thus significantly reducing the risk of loss of yield. This is an important aspect which needs to be further investigated.

tergites was found to bear a black transverse bar. The adult alate female has a mean body length of 1.74mm. The mean lengths of the siphunculus and cauda were 0.27 and 0.21mm respectively. The siphunculus was 0.18 times as long as the body and 1.27 times as long as the cauda. The antennae were dusky to dark in colour, but segments III to base of V were paler than I, II and VI. Antennal joints III, IV and VI had an average length of 0.29, 0.23 and 0.41mm respectively. The mean number of secondary rhinaria on antennal segment III was 5.18. The mean lengths of the hind-tibia, fore-tibia and fore-tarsus were 0.88, 0.64 and 0.11mm respectively.

The aphid was found to have five instars with a mean total development time of 165 hours. The first instar was 62 hours while the others were about 40 hours each. The apterous viviparous female had a total fecundity of 54.40 offspring, a mean reproduction rate of 2.47 progeny per day and a maximum reproduction rate of 6.00 progeny per day. It had a pre-reproductive, reproductive and post-reproductive periods of 0.95, 15.50 and 1.40 days respectively. The mean longevity after the adult moult was 17.85 days. The alate viviparous female had a total fecundity of 22.95 offspring, a mean reproduction rate of 1.35 progeny per day and a maximum reproduction of 2.90 progeny per day. The pre-reproductive, reproductive and post-reproductive periods were 2.10, 9.25 and 0.30 days respectively. The mean longevity after the adult moult was 11.65 days.

The experiment on post/plant relationship was done in a glasshouse. Groundnut seeds were planted in clays pot and the seedlings thinned to one plant per pot. The pots were randomly separated into eight sets of three pots each representing a treatment. Ten non-viruliferous nymphs of A. craccivora per leaf were placed on each groundnut seedling at weekly intervals beginning from seedling emergence to six weeks after seedling emergence respectively. In the control 1g carbofuran was applied at planting to the soil in each of the three pots to prevent aphids infesting the plants. The effect of aphid infestation on growth was measured by observing the mean height and the number of leaflets produced at weekly intervals. There was no significant difference in terms of plant height or number of leaves at the level of aphid infestation used. On pest/disease/plant relationship, observations made on the different symptoms expressed by groundnuts affected by the rosette virus revealed that there were both the green and chlorotic rosette symptoms in the glasshouse and on the field. There were more green than chlorotic rosetted plants.

Preliminary trials on the control of the aphid were conducted both in the glasshouse and on the field with seed dressing and granular formulations of insecticides. Viruliferous and non-viruliferous A. craccivora were separately used in the trials. The insecticides were applied at two different rates. Ten adult aphids

were placed in a clip-on leaf cage and the latter clipped on to the youngest opened groundnut leaflet with the half of the cage containing the aphids placed on the underside of the leaflet. Observations were made 24 hours after placing the aphids on the plants. The numbers of normal (live), moribund and dead aphids were recorded. The percentage mortality was calculated as the percentage of dead-plus-moribund. Rosetted plant count was started as soon as the symptoms appeared on any one treatment. The placement of aphids on the plants was stopped six weeks after germination. All the insecticides tested were effective in controlling the aphids except primicarb 1% and 0.5% slurry seed treatment. The results on the control of the rosette disease were not conclusive, although Thimet 10G seemed to give the best protection against the virus infection.

Appendix 1

MEASUREMENTS OF BODY LENGTHS, ANTENNAE, SIPHUNCULUS AND CAUDA AND THEIR RATIOS FOR APTEROUS AND ALATE VIVIPAROUS FEMALES OF A. CRACCIIVORA (in mm).

No.	Body		Antenna		Siphunculus		Cauda		Siphunculus			
	Apterae	Alates	Apterae	Alates	Apterae	Alates	Apterae	Alates	Apterae	Alates		
1	1.47	1.51	1.220	0.929	0.360	0.270	0.230	0.179	0.300	0.200	1.167	1.360
2	1.57	1.61	1.200	0.762	0.400	0.260	0.255	0.161	0.290	0.210	1.379	1.230
3	1.60	1.80	1.185	0.741	0.295	0.295	0.131	0.164	0.280	0.200	1.050	1.238
4	1.75	1.89	1.215	0.694	0.230	0.295	0.131	0.156	0.300	0.210	0.767	1.405
5	1.51	1.60	1.115	0.738	0.109	0.255	0.266	0.159	0.270	0.200	1.481	1.275
6	1.61	1.78	1.220	0.758	0.280	0.285	0.217	0.160	0.230	0.220	1.522	1.295
7	1.65	1.69	1.200	0.727	0.420	0.250	0.255	0.148	0.310	0.210	1.355	1.190
8	1.70	1.62	1.215	0.715	0.435	0.280	0.266	0.173	0.260	0.210	1.740	1.333
9	1.79	1.76	1.105	0.617	0.335	0.290	0.187	0.165	0.290	0.220	1.155	1.318
10	1.55	1.65	1.112	0.717	0.390	0.290	0.252	0.176	0.270	0.210	1.444	1.381
11	1.58	1.75	1.230	0.778	0.130	0.270	0.272	0.154	0.300	0.220	1.433	1.227
12	1.60	1.70	1.030	0.687	0.345	0.290	0.230	0.171	0.270	0.210	1.278	1.381
13	1.54	1.86	1.215	0.789	0.365	0.260	0.237	0.140	0.290	0.230	1.259	1.130
14	1.67	1.85	1.200	0.719	0.430	0.270	0.267	0.232	0.310	0.200	1.397	1.350
15	1.63	1.78	1.125	0.690	0.390	0.280	0.239	0.219	0.280	0.210	1.393	1.333
16	1.66	1.68	1.215	0.732	0.370	0.200	0.223	0.220	0.270	0.200	1.370	1.000
17	1.77	1.79	1.155	0.653	0.390	0.160	0.220	0.216	0.280	0.210	1.393	0.762
18	1.69	1.81	1.115	0.660	0.375	0.280	0.222	0.204	0.260	0.200	1.442	1.400
19	1.82	1.81	1.015	0.558	0.410	0.260	0.225	0.227	0.300	0.210	1.367	1.238
20	1.79	1.83	1.105	0.617	0.430	..	0.240	0.235	0.270	0.220	1.593	..
MEAN	1.643	1.740	1.164	0.709	0.380	0.265	0.230	0.183	0.281	0.210	1.350	1.267

NO.	CORNICLE		ANTENNUL JOINTS				TIBIA		FOR TARSUS		NO. OF SENSORIA				
	1	2	3	4	5	Hind	Fore	1	2						
1	0.350	0.270	0.315	0.295	0.185	0.250	0.370	0.430	0.950	0.910	0.840	0.690	0.119	0.105	6.000
2	0.400	0.260	0.360	0.270	0.250	0.215	0.370	0.410	0.990	0.860	0.660	0.640	0.115	0.119	5.500
3	0.350	0.295	0.250	0.300	0.226	0.230	0.371	0.430	1.020	0.920	0.646	0.670	0.114	0.100	6.000
4	0.230	0.295	0.250	0.335	0.155	0.250	0.360	0.445	0.570	0.940	0.639	0.690	0.116	0.120	5.500
5	0.400	0.255	0.325	0.275	0.235	0.230	0.260	0.400	0.960	0.850	0.600	0.625	0.119	0.120	4.000
6	0.350	0.285	0.335	0.305	0.205	0.240	0.360	0.410	1.025	0.920	0.645	0.670	0.110	-	4.000
7	0.420	0.250	0.370	0.315	0.260	0.240	0.385	0.410	1.09	0.870	0.740	0.650	0.115	0.100	5.000
8	0.435	0.280	0.350	0.310	0.250	0.240	cut	0.410	1.125	0.905	0.710	0.655	0.120	0.115	6.000
9	0.335	0.290	0.360	0.295	0.240	0.225	0.360	0.425	0.960	0.900	0.665	0.670	0.120	0.120	5.000
10	0.390	0.290	0.255	0.300	0.210	0.230	0.305	0.430	0.870	0.895	0.560	0.665	0.100	0.120	4.000
11	0.430	0.270	0.290	0.290	0.240	0.230	0.270	0.995	0.080	0.630	0.630	0.640	0.110	0.126	5.000
12	0.345	0.290	0.255	0.195	0.250	0.330	0.410	0.800	0.910	0.500	0.700	0.110	0.130	0.130	5.000
13	0.365	0.260	0.340	0.275	0.245	0.225	0.360	0.405	1.00	0.895	0.635	0.670	0.100	0.110	6.000
14	0.430	0.270	0.390	0.215	0.270	0.240	0.420	0.405	1.08	0.840	0.680	0.645	0.110	0.115	5.000
15	0.390	0.280	0.325	0.285	0.235	0.250	0.395	0.435	0.970	0.900	0.670	0.670	0.120	0.110	5.000
16	0.370	0.200	0.310	0.265	0.235	0.170	0.420	0.380	0.950	0.710	0.650	0.550	0.115	0.100	4.000
17	0.390	0.160	0.350	0.250	0.240	-	0.400	-	1.035	-	0.685	0.645	0.115	-	6.000
18	0.375	0.280	0.280	0.295	0.285	0.235	0.355	0.415	0.885	0.915	0.605	0.620	0.105	-	5.500
19	0.410	0.260	0.340	0.280	0.245	0.215	0.440	0.410	1.005	0.875	0.665	0.640	0.120	0.105	5.000
20	0.430	0.285	0.360	0.300	0.215	-	0.420	-	1.015	-	0.620	-	0.120	-	-
MEAN	0.380	0.265	0.321	0.288	0.225	0.231	0.372	0.414	0.965	0.833	0.645	0.653	0.113	0.112	5.184

Appendix 3

DETAILED RESULTS OF NYMPHAL GROWTH AND DEVELOPMENT OF A. CRACCIVORA
 FOR EXPT. 1 TIME SET-UP: 1500 HOURS. THE PARENTS WERE REMOVED: 300 HOURS.

Petri dish Number	HOURS AFTER REMOVAL OF PARENTS																		
	33		57		81		105		129		153		177		201		225		
	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	
1	10	0	2e	0	3e	0	3e	0	3e	0	3e	0	3e	0	3e	0	3e	0	3e
2	0	0	1	0	4	1	4	1	4	3	0	0	0	0	0	0	0	0	0
3	1	0	1	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0	0
4	4	3	4	3	4	4	2	4	1A	1	3	3	3	1A	3	2	2A	1	0
5	4	1	4	3	4	4	1	4	1A	4	3	1A	2	2	1	2	2A	2	0
6	3	0	3	2	3	3	1	2	1A	2	2	2	2	0	0	0	0	0	0
7	0	5	8	8	8	6	5	5	3A	4	1	1	1	0	1	1A	1	0	0
8	1	0	1	2	1	1	0	1	1	1	0	0	0	0	0	0	0	0	0
9	2	0	2	0	2	2	1	2	2	2A	0	0	0	0	0	0	0	0	0
10	3	0	4	2	3	0	3	3	3	0	3	2	3	2	3	3A	1	0	0
11	2	1	3	2	2	1	2	2	1	2	1	2	1A	1	2	1A	0	0	0
12	1	0	1	1	1	1	0	1	0	0	1	1A	0	0	0	0	0	0	0
13	2	0	2	1	2	1	1	2	2	0	2	2	2	2	2	2A	0	0	0
14	4	0	2	1	2	0	2	2	2	0	2	1A	2	1	0	1	1A	0	0
15	7	6	7	7	6	6	5	5	5	5	2	2A	1	0	0	0	0	0	0
16	3	2	3	1	3	2	1	3	1	3	3	2	3	1A	0	2	2A	0	0
17	3	1	3	3	3	1	1	1	1A	0	0	0	0	0	0	0	0	0	0
18	3	2	3	3	3	0	3	3	3	0	2	2	2	2	2	2A	1	0	0
19	2	0	2	0	2	1	0	0	0	0	0	0	0	0	0	0	0	0	0
20	4	2	4	0	3	3	2	3	1A	0	2	2	2	2	2	2A	2	0	0

Appendix 4

DETAILED RESULTS OF NYMPHAL GROWTH AND DEVELOPMENT OF A. CRACCIOPORA
 FOR EXPT. II TIME SET-UP: 1500 HOURS. TIME PARENTS WERE REMOVED: 900 HOURS.

Petri dish Number	HOURS AFTER REMOVAL OF PARENTS															
	33	57	21	105	129	153	177	201								
	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N
1	2	0	2	2	0	2	2	2	2	0	2 2A	0	0	0	0	0
2	1	0	1	0	1	1	1	1	0	1	0	1 1A	1	0	0	0
3	4	0	4	3	4	1	4	4	2	4	1	4 4A	0	0	0	0
4	2	1	2	0	2	1	2	1	2(1A)	3	1	1	1 1A	1	0	0
5	3	0	3	3	3	2	3	1	3(2A)	2	0	0	0	0	0	0
6	2	0	2	2	2	0	2	2	2	0	2 1A	1	1 1A	1	0	0
7	2	0	2	1	2	1	2	1	2	1	2 1A	1	1 1A	1	0	0
8	1	0	1	1	1	0	1	1	1 1A	1	0	0	0	0	0	0
9	2	0	2	2	2	0	2	2	2	1	2 2A	1	1 1A	1	0	0
10	1	0	1	0	1	1	1	1	1	0	1	0	1 1A	1	0	0
11	0	0	0	0	0	0	1e	0	1e	0	0	1e	0	1e	0	0
12	2	0	2	2	2	1	2	1	2	2	2 2A	0	0	0	0	0
13	2	0	2	1	2	1	2	0	2	2	0	2 2A	2	2 2A	2	0
14	2	0	2	1	2	1	2	2	2(1P)	0	1 1A	0	0	0	0	0
15	1	0	0(1D)	0	0	0	0	0	0	0	0	0	0	0	0	0
16	3	0	3	1	3	3	3	3	3	1	3 3A	1	0	0	0	0
17	3	0	3	1	3	2	3	2	3 3A	2	0	0	0	0	0	0
18	4	0	4	3	4	1	4	4	4	2	4 4A	0	0	0	0	0
19	2	0	2	0	2	0	2	1	2	1	2 2A	2	2 2A	2	0	0
20	3	0	3	0	3	2	2	2	2(ID)	0	2	1	2 2A	1	0	0
Total	42	1	41	23	41	13	41	28	40	18	34	9	16	15	1e	0

Exuviae per nymph	0.02	0.56	0.44	0.68	0.45	0.26	0.94
Cumulative mean of exuviae/ nymph	0.02	0.58	1.02	1.70	1.15	2.41	3.35

N = Nymph A = Adult
E = Exuviae D = Dead
e = Egg

FOR EXPT. III TIME SET-UP: 1500 HOURS. TIME PARENTS WERE REMOVED: 900 HOURS.

Petri dish number	HOURS AFTER REMOVAL OF PARENTS																	
	33		57		81		105		129		153		177		211		225	
	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E	N	E
1	1	0	1	1	1	0	1	1	1	1	1	1	1	0	0	0	0	0
2	1	0	1	0	1	1	1	1	1	0	1	0	1	1	0	0	0	0
3	1	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0
4	2	1	2	0	2	1	2	1	2	1	1	1	1	0	0	0	0	0
5	4	1	4	3	4	4	4	4	1	2	1	2	1	2	2	2	2	0
6	2	0	2	2	2	0	2	2	2	0	2	1	1	0	1	0	0	0
7	8	5	8	8	8	6	8	5	5	3	1	1	1	0	1	1	0	0
8	1	0	1	1	1	0	1	1	1	1	0	0	0	0	0	0	0	0
9	2	0	2	0	2	2	2	1	1	2	0	0	0	0	0	0	0	0
10	1	0	1	0	1	1	1	1	1	1	0	1	1	0	1	0	0	0
11	2	1	2	2	2	1	2	1	2	1	2	1	2	1	1	1	0	0
12	2	0	2	2	2	1	2	1	2	2	0	2	0	0	0	0	0	0
13	2	0	2	2	1	2	2	1	2	2	0	2	0	0	0	0	0	0
14	2	0	2	1	2	1	2	2	2	2	0	2	0	0	0	0	0	0
15	7	6	7	7	7	6	7	5	5	2	2	1	2	0	0	0	0	0
16	3	0	3	1	3	3	3	3	3	3	1	0	0	0	0	0	0	0
17	3	1	3	3	3	1	1(20)	1	0	1	0	0	0	0	0	0	0	0
18	4	0	4	3	4	1	4	4	4	2	0	0	0	0	0	0	0	0
19	2	0	2	0	2(10)	0	1(10)	0	0	0	0	0	0	0	0	0	0	0
20	3	0	3	0	3	2	3	2	2(10)	0	2	1	0	2	1	0	0	0
Total	53	15	53	36	53	33	50	35	42	27	18	11	11	7	4	3	0	0

Appendix 5 (cont'd)

Exuviae per nymph	0.28	0.68	0.62	0.70	0.56	0.61	0.66	0.75
Cumulative mean of exuviae/nymph	0.28	0.96	1.58	2.28	2.92	3.53	4.17	4.92

W = Nymph A = Adult
E = Exuviae D = Dead
e = Egg.

Appendix 6

REGRESSION ANALYSIS OF THE RESULTS OF
NYMPHAL GROWTH AND DEVELOPMENT OF A. CRACCIVORA

Observation	Hours (X_1)	X_1^2	Cumulative mean of exuviae per nymph (X_2)	X_2^2	SP = $X_1 \cdot X_2$
1	33	1089	0.2433	0.0592	8.0289
2	57	3249	0.8933	0.7980	50.9181
3	81	6561	1.4633	2.1412	118.5273
4	105	11025	2.1133	4.4660	221.8965
5	129	16641	2.6433	6.9870	340.9857
6	153	23409	3.1900	10.1761	488.0700
7	177	31329	3.8400	14.7456	679.6800
8	201	40401	4.6500	21.6225	434.6500
Total	936	133704	19.0365	60.9956	2842.7565
	X_1	X_1^2	X_2	X_2^2	SP = $X_1 \cdot X_2$

$$\text{Correlation Coefficient (r)} = \frac{\sum_{i=1}^n X_{1i} \cdot X_{2i} - \frac{X_1 \cdot X_2}{N}}{\sqrt{(\text{SSX}_1 - \text{cf}) (\text{SSX}_2 - \text{cf})}}$$

where $\frac{X_1 \cdot X_2}{N} = (\text{cf}) = \text{Correction Factor}$
 and $\sum_{i=1}^n X_{1i} \cdot X_{2i} = (\text{SP}) = \text{Sum product.}$

$$r = \frac{2842.7565 - \frac{936 \times 19.0365}{8}}{\sqrt{(133704 - \frac{(GT)^2}{N}) (60.9956 - \frac{(GT)^2}{N})}}$$

where $\frac{(GT)^2}{N} = \frac{X_1 \cdot X_2}{N} = \text{Correction Factor}$

$$r = \frac{2842.7565 - 2227.2705}{\sqrt{(133704 - 109512) (60.9956 - 45.2985)}}$$

$$r = \underline{\underline{0.9987}}$$

$$\text{Regression Coefficient (b)} = \frac{\text{SP}_{yx}}{\text{SS}_x}$$

where x = hours

y = Cumulative exuviae per nymph.

$$b = \frac{615.486}{24192}$$

$$= \underline{\underline{0.025}}$$

Regression.

$$\bar{y} = a + bx$$

$$a = \bar{y} - b$$

$$a = 2.38 - 0.025 (117)$$

$$a = \underline{\underline{-0.55}}$$

$$y = -0.55 + 0.025 (33) = 0.275$$

$$(57) = 0.875$$

$$(81) = 1.475$$

$$(105) = 2.075$$

$$(129) = 2.675$$

$$(153) = 3.275$$

$$(177) = 3.875$$

$$(201) = 4.475$$

Testing for significance.

$$t = \frac{r}{\sqrt{(1-r^2)}} \cdot \sqrt{n-2}$$

$$t = \frac{0.9987}{\sqrt{1-0.9974}} \cdot \sqrt{8-2}$$

$$t = 48.06$$

From the tables t values at 7 degrees of freedom

= 2.365 at 5% and

3.499 at 1%

Therefore since the calculated value of t is greater than the value of t from the tables at 5% and 1% levels of significance, the result is significant.

Appendix 7

FECUNDITY OF APTEROUS VIVIPAROUS FEMALE OF *APHIS CRACCIVORA* KOCH SET UP ON 29.5-80

CASE NO.	NUMBER OF OFFSPRING PRODUCED DAILY																				DATE	DATE	PPP ¹	PPP ²		
	1-6	2-6	3-6	4-6	5-6	6-6	7-6	8-6	9-6	10-6	11-6	12-6	13-6	14-6	15-6	16-6	17-6	18-6	19-6	20-6					21-6	22-6
1	2	0	2	1	3	2	5	4	6	4	3	4	2	1	3	3							2-6-80	18-6-80	2	16
2	11	0	3	2	0	0	2	2	3	5	3	0	1	1	4								3-6-80	18-6-80	2	15
3	5	5	3	10	6	3	2	9	3	3	3	4	3	2	3	1	0	1					2-6-80	20-6-80	1	18
4	8	0	3	0	3	6	5	3	6	6	5	3	0	0	2	3	2	5	1				1-6-80	21-6-80	1	20
5	3	5	5	7	7	8	3	7	4	3	2	4	1	2	1	2							1-6-80	20-6-80	1	16
6	4	0	4	6	2	4	2	5	8	5	4	8	3	3	4	2							1-6-80	20-6-80	1	16
7	3	12	5	11	10	6	3	6	8	3	2	3	0	0	1	1	2						2-6-80	20-6-80	0	19
8	6	2	3	9	7	5	4	8	4	6	2	6	3	4	3	1	5	1					2-6-80	22-6-80	0	22
9	5	10	7	11	4	2	4	2	1	4	3												2-6-80	13-6-80	1	11
10	9	12	11	9	6	5	5	3	2	5	2	2	0	1	3	1	3	3					2-6-80	16-6-80	0	13
11	5	6	5	6	3	3	1	5	2	3	2	2	0	1	3	1	3	3					3-6-80	19-6-80	1	18
12	7	6	10	6	2	2	2	0	0	1	0	1	3	2									1-6-80	19-6-80	0	15
13	5	4	15	12	5	2	4	0	2	1	2	2	3	1									3-6-80	16-6-80	1	14
14	3	3	3	3	3	3	2	=	2	1	1	3	5	2	1	1							1-6-80	18-6-80	1	16
15	3	8	2	3	4	4	2	5	3	1	2												3-6-80	13-6-80	1	11
16	4	6	5	4	3	5	2	0	0	0	2	5	6	3	1	1	0	2	6	1			2-6-80	23-6-80	2	19
17	7	0	4	5	3	2	1	0	0	2	2	2	2	1	1	3							1-6-80	16-6-80	1	16
18	5	0	0	3	4	2	2	1	2	1	1	1	2	1	1	4							1-6-80	18-6-80	1	16
19	11	9	5	4	8	2	1	0	5	0	8	5											1-6-80	18-6-80	1	16
20	6	7	4	5	4	1	1																2-6-80	18-6-80	1	12
Total	11	93	109	95	120	88	56	51	64	58	54	52	57	35	25	23	32	16	14	12	13	2	1-6-80	9-6-80	1	7

REPRODUCTION PERIODS: 1-6-80 5.24 4.94 4.40 3.30 2.55 3.20 2.50 2.70 2.60 2.85 1.75 1.25 1.15 1.60 0.80 0.70 0.60 0.15 0.10 0.20

REPRODUCTION PERIODS: 1 Pre-reproductive period. 2 Reproductive period. 3 Post-reproductive period. 4 Reproductive period.

Appendix 9

MEAN DAILY TEMPERATURE AND MEAN DAILY PERCENTAGE
RELATIVE HUMIDITY (% r.h) FOR FECUNDITY OF APTEROUS
VIVIPAROUS FEMALE OF A. CRACCIVORA

DATE	MEAN DAILY TEMP. (°C)	MEAN DAILY % r.h
		82.50
29-5-80	27.25	85.25
30-5-80	28.60	86.25
31-5-80	27.70	84.95
1-6-80	28.45	85.50
2-6-80	27.95	89.00
3-6-80	28.00	84.00
4-6-80	27.45	84.00
5-6-80	26.50	81.50
6-6-80	27.00	81.50
7-6-80	28.00	80.50
8-6-80	28.25	76.50
9-6-80	26.00	84.00
10-6-80	26.70	89.00
11-6-80	26.25	90.00
12-6-81	26.00	89.00
13-6-80	26.50	90.00
14-6-80	26.50	89.00
15-6-80	27.50	89.50
16-6-80	27.25	90.00
17-6-80	25.75	90.00
18-6-80	25.50	72.00
19-6-80	35.25	70.50
20-6-80	31.25	63.88
21-6-80	32.25	69.00
22-6-80	30.95	
MEAN	27.96	83.07

Appendix 10

MEAN DAILY TEMPERATURE AND MEAN DAILY PERCENTAGE
RELATIVE HUMIDITY (% r.h) FOR FECUNDITY OF ALATE
VIVIPAROUS FEMALE OF A. CRACCIVORA

DATE	MEAN DAILY TEMP. (°C)	MEAN DAILY r.h. (%)
29-5-80	27.25	82.50
30-5-80	28.60	85.25
31-5-80	27.70	86.25
1-6-80	28.45	84.95
2-6-80	27.95	85.50
3-6-80	28.00	89.00
4-6-80	27.45	84.00
5-6-80	26.50	84.00
6-6-80	27.00	81.50
7-6-80	28.00	81.50
8-6-80	28.55	80.50
9-6-80	26.00	76.50
10-6-80	26.70	84.00
11-6-80	26.25	89.00
12-6-80	26.00	90.00
13-6-80	26.50	89.00
14-6-80	26.50	90.00
15-6-80	26.50	89.00
16-6-80	27.50	89.50
	27.25	89.50
MEAN	27.27	85.37

Appendix II

STATISTICAL ANALYSIS OF THE RESULTS OF GROUNDNUT
PLANT HEIGHT PER WEEK.

TABLE (i) Showing plant height per week of each replication (R)

Week	R ₁	R ₂	R ₃	Total
1	42.00	46.10	63.00	151.90
2	73.80	80.70	107.80	262.30
3	92.30	99.40	111.50	315.20
4	102.20	109.80	135.00	347.00
5	113.90	124.10	148.70	386.70
6	128.40	139.20	161.50	429.10
Total	553.40	599.30	740.50	1893.20

$$\text{Correction Factor (C.F.)} = \frac{(GT)^2}{n}$$

$$= \frac{(1893.20)^2}{144}$$

$$= \underline{\underline{24890.32}}$$

$$\text{Total SS} = \sum Xi^2 - \text{C.F.}$$

$$= \underline{\underline{193672.44}}$$

$$\text{Replication SS} = \frac{\sum Ri^2}{48} - \text{C.F.}$$

$$= \frac{553.40^2 + 599.30^2 + 740.50^2}{48} - 24890.32$$

$$= \underline{\underline{396.186}}$$

$$\begin{aligned} \text{Weeks SS} &= \frac{\sum X_i^2}{24} - \text{C.F.} \\ &= \underline{\underline{2023.431}} \end{aligned}$$

TABLE (ii) showing totals of treatments and weeks.

Weeks	TREATMENTS							
	1	2	3	4	5	6	7	8
1	18.50	20.00	19.90	17.00	18.00	15.90	20.80	21.00
2	20.60	32.70	34.50	35.00	31.40	21.50	37.60	40.00
3	37.50	38.00	39.50	41.00	36.80	29.30	45.50	47.30
4	42.70	44.20	43.30	45.30	38.70	34.00	47.30	51.50
5	49.90	50.90	48.00	50.90	41.70	40.00	49.80	55.50
6	54.50	54.80	54.50	57.00	45.50	46.00	54.30	58.50
Total	229.70	241.60	239.70	247.00	216.10	189.70	255.30	274.30

$$\begin{aligned} \text{Total SS of Table (ii)} &= \frac{\sum X_i^2}{3} - \text{C.F.} \\ &= \underline{\underline{2336.166}} \end{aligned}$$

$$\begin{aligned} \text{Treatment SS} &= \frac{\sum T_i^2}{18} - \text{C.F.} \\ &= \underline{\underline{254.403}} \end{aligned}$$

$$\begin{aligned} \text{Treatment SS x Week SS} &= 2336.166 - (2023.431 + 254.403) \\ &= \underline{\underline{58.332}} \end{aligned}$$

$$\begin{aligned} \text{Error SS} &= 193672.44 - (356.136 + 2023.431 + 254.403 + 58.332) \\ &= \underline{\underline{190940.08}} \end{aligned}$$

ANOVA TABLE

Source	df	SS	MSS	F values calculated Table	
Replication	2	396.186	198.093	0.9752162	3.09
Treatment	7	256.403	36.632235	0.1789176	2.10
Weeks	5	2023.731	404.6362	1.992268	2.30
Treat. x Weeks	35	58.332	1.6666285		
Error	94	19094.08	203.12851		
Total	143	193672.84			

Appendix 12

STATISTICAL ANALYSIS OF THE RESULT OF THE
NUMBER OF GROUNDNUT LEAFLETS PER WEEK

Table (iii) Showing replications (R) and weeks.

Week	R ₁	R ₂	R ₃	Total
1	42.00	42.00	53.00	137.00
2	74.00	80.00	99.00	253.00
3	99.00	106.00	125.00	329.00
4	115.00	127.00	144.00	386.00
5	137.00	166.00	155.00	463.00
6	155.00	163.00	190.00	508.00
Total	622.00	676.00	777.00	2075.00

- 105 -

$$\text{Correction Factor (C.F.)} = \frac{(GT)^2}{n}$$

$$= \frac{(2075.00)^2}{104}$$

$$= \underline{\underline{29900.173}}$$

$$\text{Total SS} = \sum X_i^2 - \text{C.F.}$$

$$= \underline{\underline{243054.82}}$$

$$\text{Replication SS} = \frac{\sum R_i^2}{43} - \text{C.F.}$$

$$= \frac{622.00^2 + 676.00^2 + 777.00^2}{43} - \text{C.F.}$$

$$= \underline{\underline{257.931}}$$

$$\text{Weeks SS} = \sum M_i^2 - \text{C.F.}$$

$$= \frac{137.00^2 + 253.00^2 + \dots + 508.00^2}{27} - \text{C.F.}$$

$$= \underline{\underline{3924.452}}$$

TABLE (iv) showing treatments and weeks.

WEEK	TREATMENT							
	1	2	3	4	5	6	7	8
1	18.00	20.00	18.00	15.00	17.00	12.00	17.00	20.00
2	29.00	36.00	35.00	30.00	28.00	22.00	31.00	41.00
3	25.00	42.00	46.00	39.00	39.00	30.00	41.00	57.00
4	38.00	49.00	53.00	48.00	48.00	37.00	50.00	63.00
5	43.00	60.00	55.00	56.00	62.00	44.00	62.00	81.00
6	54.00	59.00	67.00	66.00	54.00	59.00	61.00	87.00
Total	216.00	266.00	275.00	254.00	288.00	195.00	262.00	349.00

$$= 107$$

$$\text{Total SS of Table (iv)} = \frac{X_1^2}{3} - \text{C.F.}$$

$$\text{Treatment SS} = \frac{T_i^2}{18} - \text{C.F.}$$

$$= \frac{216.00^2 + 265.00^2 + \dots + 349.00^2}{18} - \text{C.F.}$$

$$= \underline{799.104}$$

$$\text{Treatment SS} \times \text{Week SS}$$

$$= 4956.16 - (3924.004 + 799.104)$$

$$= \underline{232.604}$$

$$\text{Error SS} = 24304.92 - (257.931 + 3924.452 + 799.104 + 232.604)$$

$$= \underline{\underline{23785.72}}$$

ANOVA TABLE

source	df	SS	MSS	F values calculated	Table
Replication	2	257.931	128.9655	0.05097	3.09
Treatment	7	799.104	114.15771	0.045116	2.10
Weeks	5	3924.452	784.8904	0.31019	2.30
Treat. x Weeks	35	232.604	6.64583		
Error	94	237850.72	2530.3268		
Total	143	243064.82			

LITERATURE CITED

- ABALU, G.O.I. (1976). Supply response to producer prices: a case study of groundnut supply to the Northern States Marketing Board. Savanna 4: 33-40.
- AERLS (1976). Spraying groundnut seed multiplication sites against aphids. Letter sent to the Chief Agricultural Officer, Ministry of Agriculture and Natural Resources, Kano, 14th June, 1976. Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria, Nigeria. pp.2.
- AERLS (1977). Groundnut production in the Northern States of Nigeria. Extension Bulletin No.2. Agricultural Extension and Research Liaison Services, Ahmadu Bello University, Zaria, Nigeria. pp.23.
- AKINFENNA, S. (1977). Groundnut and oil seeds improvement programme. Report to the Board of Governors on the Institute's Work in 1976 - 77. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. pp. 27 - 34.
- AMATE, B.G., MAIK, L.N. and POKHARKAR, R.M. (1978). Efficacies of lower doses of systemic granular insecticides for the control of aphids (Myzus persicae Sulzer), jassids (Amrasca biguttula biguttula Ishida) and thrips (Hemiothrips indicus Bank) infesting potato in Maharashtra. Journal of the Maharashtra

Agricultural Universities 3: 49 - 50.

- BANKS, C.J. and MACAULAY, E.D.M. (1964). The feeding growth and reproduction of Aphis fabae Scop. on Vicia faba under experimental conditions. Annals of Applied Biology 53: 229 - 242.
- BASU, R.C., CHAKRAVARTI, S. and RAYCHANDHURI, D.N. (1968). Records of the sexuales of Aphis craccivora Koch. (Homiptera: Aphididae) from India. Oriental Insects 2: 349 - 351.
- BLACKMAN, R. (1974). Invertebrate Types: Aphids. Ginn and Company Limited, London and Aylesbury. pp. 175.
- BLACKMAN, R. L. (1971). Variation in the photoperiodic response within natural populations of Myzus persicae (Sulzer.) Bulletin of Entomological Research 60: 533 - 546.
- BOOKER, R. H. (1963). The effect of sowing date and spacing on rosette disease of groundnut in northern Nigeria with observations on the vector, Aphis craccivora. Annals of Applied Biology 52: 125 - 131
- BROADBENT, L. (1960). Control by insecticides of the spread of plant viruses. Report of the 7th Commonwealth Entomological Conference, London. pp. 163 - 170.

- BROADBENT, L. (1976). Disease control through vector control. In viruses, Vectors and Vegetation. Ed. K. Maramosch. pp.593 - 630. Interscience, New York.
- BROADBENT, L. and MARTIN, C. (1959). The spread of plant viruses. Advances in Virus Research 6: 93 - 135.
- BURT, P.E., BROADBENT, L. and HEATHCOTE, G.D. (1960). The use of soil insecticides to control potato aphids and virus diseases. Annals of Applied Biology 48: 580 - 590
- CARTER, W. (1961). Ecological aspects of plant virus transmissions. Annual Review of Entomology 6: 347 - 370.
- COOK, W.C., BUTLER, L., WALKER, K. C. and FEATHERSTON, P.E. (1963). Granular in-furrow treatments with phorate and di-syston against the pea aphids on peas. Journal of Economic Entomology 56: 95 - 98
- COTTIER, W. (1953). Aphids of New Zealand. New Zealand Department of Scientific and Industrial Research Bulletin 106: 183-187.
- DAVIES, J. (1979). Bennisseed in Hadejia and Gumel. Noma 2: 17 - 20.
- DAVIES, J. C. (1975a). Use of menazon insecticides for the control of rosette disease of groundnuts in Uganda. Tropical Agriculture (Trinidad) 52: 359 - 367.
- DAVIES, J. C. (1975b). Insecticides for the control of the spread of groundnut rosette disease in Uganda. Pest Articles and News Summaries 21: 1 - 8.

- DAVIES, J.C. and KASULE, F.K. (1960). The control of groundnut rosette disease in Uganda. Tropical Agriculture (Trinidad) 41: 303 - 309.
- DE SOUZA JR., H.F., GIANNOTTI, O. and ALMEID, P.R. (1957). The control of early pests of cotton by means of seed treatment with new kinds of systemic insecticides. Biologica 23: 227 - 236.
- DIXON, A.F.G. (1973). Biology of Aphids pp.58. Edward Arnold (Publishers) Limited, London.
- EASTOP, V.F. (1961). A study of the Aphididae (Homoptera) of West Africa, pp.93. H.M.S.O., London.
- EASTOP, V.F. and VAN EMDEN, H.F. (1972). The insect material. In Aphid Technology. Ed. H.F. van Emden. pp.1 - 45.
- ELLIOT, H.J. and McDONALD, F.J.D. (1964). Reproduction in a parthenogenetic aphid, Aphis craccivora Koch: embryology, ovarian development and fecundity of apterae and alatae. Australian Journal of Zoology 24: 49 - 63.
- EVANS, A.C. (1954). Groundnut rosette disease in Tanganyika. 1 - Field studies. Annals of Applied Biology 41: 189 - 206.
- FAO. (1966). Agricultural Development in Nigeria, 1965 - 1980 pp. 512. Food and Agriculture Organisation of the United Nations, Rome.

- FEARIE, S.D. (Ed.) (1973). Pest Control In Groundnuts. Pest Articles and News Summaries Manual No.2 pp. 123 - 125. Centre for overseas Pest Research, London.
- FINNEY, D.J. (1971). Probit Analysis. pp.333. Cambridge University Press, Cambridge.
- HARKNESS, C., KOLAVOLE, K.B. and YAYOCK, J.Y. (1975). Groundnut research in Nigeria. Samaru Conference paper No.7. Paper presented at Technical Workshop, University of Florida, U.S.A. July 11-15, 1975.
- HARRIS, K.F. and MARANOROSCH, K. (Eds.) (1977). Aphids as Virus Vectors. pp.559. Academic Press, New York.
- HASSANEIN, H.H., EL-KADY, E.A., KHALIL, F.M. and MOFTAH, E.A.M. (1971). The effectiveness of certain systemic insecticides as cotton seed treatment against aphids infestation. Bulletin of the Entomological Society of Egypt, Economic Series 5: 227 - 233.
- HILL, D. (1975). Agricultural Insect Pests of the Tropics and their control. pp. 516. Cambridge University Press, Cambridge.
- HUGHES, R.D. and MOOLOCK, L.T. (1965). A modification of Johnson's method of rearing aphids for ecological studies. New Zealand Journal of Agricultural Science 8: 723 - 736.

- HULL, R. and ADAMS, A.M. (1968). Groundnut rosette virus and its assistor virus. Annals of Applied Biology: 62: 139 - 145.
- IAR (1978). Groundnuts and oil seeds improvement programme. Report to the Board of Governors on the Institutes Work in 1977 - 78. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. pp.40.
- JOHNSON, B. and BIRKS, P.R. (1960). Studies on wing polymorphism in aphids. 1 - The developmental process involved in production of different forms. Entomologia Experimentalis et Applicata 3: 27 - 339.
- JONES, M. G. (1967). Observations on two races of the groundnut aphid, Aphis craccivora. Entomologia Experimentalis et Applicata: 10: 31 - 38.
- JUDGE, F.D. (1963). Polymorphism in a subterranean aphid, Pemphigus husarius. 1. Factors affecting the development of sexuaparae. Annals of the Entomological Society of America 61: 819 - 827.
- KENNEDY, J.S. (1960). The behavioural fitness of aphids as field vectors of viruses. Report of the 7th Commonwealth Entomological Conference, 1960. London. pp. 165 - 168.

- KENNEDY, J.S., BOOTH, C.O. and KERSHAN, H.J.S. (1959). Host finding by aphids in the field. II. Aphis fabae Scop. (Gynoparae) and Brevicoryne brassicae L. with a reappraisal of the role of host finding behaviour in virus spread. Annals of Applied Biology 47: 424 - 444.
- KENNEDY, J.S., DAY, H.F. and EASTOP, V.F.A. (1962). Conspectus of Aphids as Vectors of Plant Viruses. pp. 114. Commonwealth Institute of Entomology, London.
- KENNEDY, J.S. and STROYAN, H.L.G. (1959). Biology of aphids. Annual Review of Entomology 4: 139 - 160.
- KLESSER, P.J. (1968). Green rosette virus of groundnuts in South Africa. South African Journal of Agricultural Science 11: 415 - 422.
- LEES, A.D. (1959). The role of photoperiod and temperature in the development of parthenogenetic and sexual forms in the aphid Megoura viciae Buckton. 1. The influence of these factors on apterous virginoparae and their progeny. Journal of Insect Physiology 3: 92 - 117.
- MARKOVITCH, S. (1924). The migration of Aphididae and the appearance of the sexual forms as affected by the relative length of daily light exposure. Journal of Agricultural Research 27: 513 - 522.
- HISARI, S.M. (1975). Insects and other arthropod pests of groundnuts in northern Nigeria. Samaru Agricultural Newsletter 17: 4 - 9.

- NIRULA, K.K. and KUMAR, R. (1969). Soil application of systemic insecticides for control of aphid vectors and leaf roll and 'Y' viruses in potato. Indian Journal of Agricultural Science 39: 699 - 703.
- OETTING, R.D., NORISHITA, F.S., JEFFERSON, R.H., HUMPHREY, M.A. and BESENER, S.T. (1977). Aphid control on chrysanthemums and carnations. California Agriculture 3: 7 - 9.
- OKUSANYA, B.A.H. and WATSON, N.A. (1966). Host range and some properties of groundnut rosette virus. Annals of Applied Biology 58: 377 - 387.
- PATKAR, M.B., NIRULA, K.K. and TIDKE, P.N. (1969). Possibility of producing healthy seed potato in the Deccan Plateau by controlling aphid vectors. Indian Journal of Agricultural Science 30: 848 - 853.
- POND, D.D. (1963). Control of potato aphids with systemic insecticides. Journal of Economic Entomology 52: 227-230.
- POND, D.D. (1964). Field control of potato leaf roll virus with systemic insecticides. American Potato Journal 41: 14 - 17.
- POSNETTE, A. F. (1960). Some aspects of virus spread among plants by vectors. Report of the 7th Commonwealth Entomological Conference, 1960. London. pp. 162 - 165.

- RADKE, S.G., BENTON, A.W. and YENDOL, M.J. (1973). Effect of temperature and light on the development of cowpea aphid, Aphis craccivora Koch. Indian Journal of Entomology 35: 107 - 118.
- RAYLONDS, H.T., FUKUTO, T.R., METACALF and MARCH, R. B. (1957). Seed treatment of field crops with systemic insecticides. Journal of Economic Entomology 55: 2 - 3
- ROSSEL, H. W.(1976). Some preliminary results of investigations on groundnut rosette disease in northern Nigeria. Minutes of the International Symposium on Field Pest of Groundnut and Millet. Kaolack, Senegal, 21 - 23 April, 1976. pp. 138 - 142. African Groundnut Council, Lagos, Nigeria.
- ROSSEL, H.W.(1977). Some observations and experiments on groundnut rosette virus and its control in Nigeria. Samaru Miscellaneous Paper 71. Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. pp. 14.
- SMITH, K.H. (1958). Transmission of plant viruses by arthropods. Annual Review of Entomology 3: 469 - 482.
- STOREY, H.H. and BOTTONLEY, A.H. (1928). Rosette disease of the peanut. Annals of Applied Biology 15: 26 - 45.
- STOREY, H.H. and RYLAND, A.K. (1957). Viruses causing rosette and other diseases in groundnuts. Annals of Applied Biology 45: 318-326.

- SUBBARAYUDU, S. and HARKNESS, C. (1980). Screening advanced breeding lines and varieties of groundnut for resistance to chlorotic rosette virus disease. Paper presented at the 10th Annual Conference of the Nigerian Society for Plant Protection, 12-14 February, 1980. Institute for Agricultural Research and Faculty of Agriculture, Ahmadu Bello University, Zaria, Nigeria.
- WATSON, M.A. and PLUMP, R.T. (1972). Transmission of plant pathogenic viruses by aphids. Annual Review of Entomology 17: 425 - 452.
- WUDIL, J. (1978). Problems of groundnut production in Kano State. Proceedings of the National Seminar on Groundnut Production, Bagauda Lake Hotel, Kano, February, 1978. The Nigerian Groundnut Board, Kano and the Institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria. pp. 19 - 21.