CONTROL OF' GROUNDNUT ROSETTE VIRUS AND ITS VECTOR, *APHIS CRACCIVORA* KOCH.

BY

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CERTIFICATION

This thesis entitled 'CONTROL OF GROUNDNUT ROSETTE VIRUS AND ITS VECTOR APHIS CRACCIVORA KOCH' by Yahaya Mafara Abubakar meets the regulations governing the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to scientific knowledge and literary presentation.

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DEDICATION

This work is dedicated to the blessed memory of my dearest father, Late Alhaji Abubakar Barmo who took me to School and to my wife, Hauwa Kulu for being a constant source of joy.

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ABSTRACT

The study was conducted .with a view to determine the effects of plant population, sowing aates, insecticides and interaction between the three factors *on* the epidemiology and control of groundnut rosette virus and its aphid vector, Aphis craccivora Koch. Results obtained show that irrespective of planting date or plant density, peak populations of Aphis craccivora are attained between the last week of July and first week of August. Groundnuts are found to be colonised starting at germination especially when planted late.

During the two years of trials, rosette incidence was about 2%. However, the severity was higher and the disease spread much faster on control plots than on insecticide treated plots. Insecticide treatment did not prevent primary infection of rosette.

Cheilomenes sulphurea, C. vicina and Scymnus sp, (Coccinellidae) and Xanthogramma aegypticum, Paragus borbonicus (Syrphidae) were the most commonly recorded aphid natural enemies, but did not exert significant suppressing effect. Their role in the integrated control of the aphids as vectors is discussed.

Fewer aphids and higher pod yield and shelling percentage were recorded on insecticide treated,

ABSTRACT (Cont'd)

earlier and more densely planted groundnuts. Planting date had stronger--influence on groundnut-yield than spacing or insecticide treatment. Carbofuran applied as Furadan 3G proved superior to ethiofencarb (Croneton 500 E.G.), pirimicarb (Pirimor ED Spray) and carbosulfan (Marshall 5% Dust) in aphid control. Application of carbofuran at 0.75kg a.i./ha proved as effective as 1.0 and 1.5kg a.i./ha during the first 30 days of planting. The various interactions of planting date, plant population and insecticide treatments on aphids and other parameters such as yields are discussed.

CHAPTER 1

INTRODUCTION

The Groundnut Rosette Disease, transmitted by the cowpea aphid, Aphis craccivora Koch, is extremely important because of the serious losses it induces. The rosette virus is one of the three most destructive viruses infecting groundnuts, the other two being the peanut mottle virus and the bud necrosis virus (Kuhn, 1965; Behncken, 1970; Bock, 1973; Gen and Ting, 1973).

In Nigeria, rosette was not considered as an important disease of groundnuts in the main producing areas of the country prior to 1975. Infection was estimated at less than three per cent in normal years (Yayock et al., 1976). The importance of the disease was realized in 1975 when a disastrous and unprecedented rosette epiphytotic occurred and affected the main producing areas of the northern part of the country. This resulted in a near total loss of the crop as out of an estimated total production area of 0.8 to 1.2 million hectares, about 0.7 million ha. were completely destroyed by the disease (Harkness et al., 1976). The rosette epiphytotic revealed the vulnerability

of the local varieties, which are highly susceptible to the virus, and the need for the development of reliable control measures.

In Nigeria, two methods of control are being investigated for use against the groundnut rosette virus and its vector, Aphis craccivora Koch. The first is the use of rosette-resistant varieties, work on which began in 1962 at Mokwa (A'Brook, 1965). Two resistant varieties - M25.68 and ex-Bambey (69-101) were recommended in 1972 for general use through the Southern Guinea zone. Later, RMP 12 and RMP 91 were identified as suitable resistant varieties for growing in the arid northern areas where the main crop is produced. However, the performance of RMP 12 and RMP 91 has not yet been assessed on a wide scale and they are not yet available for large scale distribution to farmers in the main growing areas. The second approach is the control of the aphid vector, A. craccivora, by using either modified agronomic practices, such as early sowing and close spacing, or by the use of insecticides. Early sowing and close spacing have been reported to reduce the population of the aphid and the incidence of the rosette (A'Brook, 1964; Booker, 1963), but such practices are effective only when the aphids are few and the

incidence of the virus is low. They would be ineffective against epidemics such as that of 1975. In the case of insecticides, very little attention has been given to their use against the rosette virus by controlling its vector, A. craccivora. In fact, even after the 1975 epidemic, most of the insecticides tested were observed under laboratory or glasshouse conditions and have therefore not really been assessed on a wide scale in the field.

Natural enemies of aphids, such as the parasitic wasps, Aphidius spp. (Hymenoptera) and the predatory Syrphids (Diptera) and Coccinellids (Coleoptera) were recorded feeding on A. craccivora (Booker, 1963), but the role they play in regulating the population of the aphid is not known. Misari (1975) stated that the use of biological control measures against aphids as vectors on groundnuts in Nigeria was still remote.

In view of some of the problems of control mentioned above, the present study was undertaken in the field to examine the effects of plant spacing, planting date, insecticides and natural enemies on the aphid vector, A. craccivora. The combining of more than one control technique in an integrated approach was with a view to achieving a more reliable control

of the rosette virus and its vector, A. craccivora. The following were the main objectives:

1. To determine the effects of plant population, insecticides, sowing dates and the interaction between the three factors on the epidemiology and control of groundnut rosette virus and its vector Aphis craccivora Koch.

2. To find out whether natural enemies (Syrphidae and Coccinellidae) can play a significant role in the integrated control of A. craccivora.

CHAPTER 2

LITERATURE REVIEW

2.1 The crop

Groundnut, Arachis hypogaea L. (Papillionaceae) is an important annual leguminous crop cultivated in many warm tropical and sub-tropical countries and also in some temperate countries. It is grown on about 19 million hectares annually, chiefly in India (33.5%), Nigeria (8.3%), the United States of America (5.6%), Senegal (6.5%) and Brazil (2.6%) (FAO, 1967).

The crop was introduced into Nigeria from South America by the early Portuguese and Spanish explorers in the 16th century (Hammons, 1973). It is cultivated for its seeds which contain up to 50 per cent of a non-drying oil and about 30 per cent protein. Its haulms are used as hay for livestock feed.

In Nigeria, about 0.8 to 1.2 million hectares of groundnuts are grown annually, mainly by the peasant farmers (Harkness et al., 1976). The bulk of the crop is grown in the northern states, mainly Bauchi, Borno, Gongola, Kaduna, Kano and Sokoto. The southern states produced only one per cent of the total output in 1970/71 (Agboola, 1979).

Total production has never been accurately recorded because production estimates are based mainly on purchases by the marketing boards, exports from Nigeria and imports of the recipient countries, while quantities consumed locally and those retained by the primary producers for planting in the following season are not recorded.

The groundnut crop is subject to attack by many invertebrate pests at all stages of its development and also during storage (Misari, 1975; Misari and Raheja, 1976). Aphis craccivora Koch is considered to be the most important aerial pest of the crop because it is a vector of the groundnut rosette virus.

2.2 Groundnut rosette disease

The groundnut rosette disease was recognized in Africa about 1907 (Zimmerman, 1907), but Storey and Bottomley (1925, 1928) were the first to establish the fact that the rosette disease was caused by a virus transmitted by the aphid, A. craccivora.

2.2.1 Distribution and economic importance

The rosette virus occurs only in Africa and it has been reported from many African Countries where groundnuts are grown (Zimmerman, 1907; Storey and

Bottomley, 1925; Hargreaves, 1933; Porteres and Legleu, 1937; Bowriquet, 1939; Soyer, 1939; Sauger et al., 1954; Vanderveken, 1961; Brunt and Bonney, 1964; Davies, 1972). The disease has a wide distribution throughout the groundnut growing areas of Africa (Panse, 1937; Evans, 1954; Booker, 1963).

The economic importance of groundnut rosette virus is closely linked with its yield reducing capability. Quantitative estimates of the importance of rosette have not been fully documented, despite the long history of scientific investigation on the virus. After the initial report of its occurrence in Tanzania (Zimmerman, 1907), it was associated with serious losses of the groundnut crop. It was considered to be one of the three most important diseases of groundnuts in South Africa (Hosking, 1933). Up to 61-80% loss in pod and haulm yields were also reported in French West Africa (Panse, 1937) and Ivory Coast (Porteres and Legleu, 1937). Early transmission of the virus by the aphid vector, especially at seedling growth stages, can severe stunting of growth and failure of the crop to set pods. Severe yield losses are therefore frequently experienced (Gibbons, 1977; Rossel, 1977; Harkness, 1977). In Nigeria, over 60 per cent yield loss was recorded in 1975 (Yayock et al., 1976).

2.2.2 Host range

The rosette virus has a limited host-range. Naturally-infected wild or cultivated host-plants other than groundnuts have never been reported from any part of the world. However, many researchers have shown that the virus can be transferred to a few plant species. Storey (1932) tested many species, mainly legumes, with no success. Soyer (1939) reported the transfer of the virus to Centrosema plumeri, but she was unable to infect groundnuts from this plant. She also obtained negative results with Euphorbia hirta and Indigofera hirsuta. Okusanya and Watson (1966) tested 33 plant species of which only two of Trifolium (T. incarnatum and T. repens), three of Chenopodium (C. amaranticola, C. hybridum and C. quinoa) and two of Nicotiana (N. clevelandii and N. rustica) proved susceptible.

In Tanzania (Evans, 1954) and Uganda (Davies, 1972), groundnut is regarded as the most important source of both the virus and its vector throughout the year. But in the Sudan (Clinton, 1962), Nigeria (Booker, 1963) and Malawi (Nutman et al., 1964) where groundnuts do not survive the harsh dry season, other sources of the virus must be sought. Since the

rosette virus can persist in the aphid vector for up to ten days (Storey and Ryland, 1955; Okusanya, 1966), there must be certain other hosts on which the virus and/or the vector pass the dry season in these areas.

2.2.3 Symptoms

Many types of rosette diseases have been discribed, based upon external variations in leaf symptoms. Workers such as Hayes (1932), Soyer (1939) and Klesser (1968), distinguished three different types while others like Storey and Ryland (1957) and Hull and Adams (1968) distinguished only two types. Hansford and Hayes (1940) briefly described six types of rosettes. Of all the rosette types described, however, two main types - Chlorotic and Green Rosettes appear to be dominant. Chlorotic rosette is most common in East and Southern Africa while green rosette is predominant in West Africa. In Nigeria, both types occur, but the form most commonly found is the green rosette (Harkness, 1977).

Storey and Bottomley (1928) described chlorotic rosette symptoms as a cessation of the growth of the axis, a reduction in the length of the petiole and in the size of the leaflets, and chlorosis,

malformation and curling of the leaflets. A plant with chlorotic rosette shows a bright yellow to white interveinal chlorosis, twisting of young terminal foliage and generalized stunting. The first symptoms mostly occur between 10 to 14 days after infection (Storey and Ryland, 1955). In the case of the green rosette, the infected plant becomes extremely stunted, with leaves much reduced in size and number and a darker green colour than normal. Distortion of leaflets does not usually occur, but there is a downward and inward rolling of the leaf margins. There is much more stunting of the plants than occurs with the chlorotic rosette.

2.2.4 Etiology

Several types or strains of rosette have been described (Hayes, 1932; Hansford and Hayes, 1940; Storey and Ryland, 1957; Smartt, 1961). Working with isolates from East and West Africa, Okusanya and Watson (1966) suggested that the rosette disease might be caused by a complex of two viruses. They believed that both chlorotic and green rosettes are manifestations or strains of the same virus. Hull and Adams (1968) provided additional evidence when they separated and distinguished two components - a

symptom-inducing component (dependent virus) which is sap transmissible, and a symptomless component (helper virus) which is transmitted by aphids alone. Bock and Perry (1967) in eastern Uganda suggested that two complexes of two or three viruses might be responsible for the rosette disease and that one virus, severe mottle virus, was common to both complexes. Despite all these research efforts over the past 50 years (Storey and Ryland, 1957; Okusanya and Watson, 1966; Adams, 1967; Watson and Okusanya, 1967; Davies, 1972; Gibbons, 1977; Harkness, 1977), the etiology of the disease still remains uncertain. However, it seems highly probable that groundnut rosette is caused by different viruses, mixtures of viruses and/or a complex of factors which could include vectors and unique environmental conditions such as suitable temperatures, relative humidity and rainfall.

2.2.5 Transmission

Aphis craccivora Koch is the only important field vector known to transmit the rosette virus. There is a persistent relationship between the virus and the vector (Watson and Roberts, 1939; Storey and Ryland, 1955; Davies and Kasule, 1964; Davies, 1975b; Rossel, 1977). Storey and Ryland (1955) found that infected

aphids tested for 24 hours on each of ten successive days without access to an outside source of virus, might infect a plant on any day up to the tenth. Minimum acquisition and infection feeding times of one day are required for good transmission (Vanderveken, 1961; Nutman et al., 1964). A period of 10 to 14 days is required from inoculation to the appearance of the first symptoms (Storey and Ryland, 1955; Farrell, 1972). Different races of A. craccivora have been found to vary in their inherent capability to transmit the rosette virus. Okusanya (1965), working with different races, found out that a Nigerian race of A. craccivora could transmit both chlorotic and green rosettes, whereas races from Uganda and Kenya could only transmit chlorotic rosette. In Ghana, Brunt and Bonney (1964) found groundnut rosette virus to be sap transmissible, while Klesser (1968) in South Africa found that some types are sap trnasmissible while others are not. In Nigeria, the groundnut rosette virus is persistently transmitted by the aphid vector, A. craccivora (Rossel, 1977). Alatae, apterae and nymphs can all transmit the virus.

Transmission by grafting is also possible as demonstrated by Storey and Bottomley (1928), in a single experiment. Transmission by Aphis gossypii Glov

under glasshouse conditions was also reported (Adams, 1966) but its importance in the field has not yet been determined.

2.2.6 Epidemiology

Rosette virus is brought into the field by immigrant infective alatae. These alatae move from plant to plant, depositing a few nymphs on each. A'Brook (1964) considers that in the reverine areas of Nigeria, alatae are the major source of primary virus infection and subsequent dissemination within the crop, and that apterae are relatively unimportant. Storey and Ryland (1955) in their work observed that alatae were sometimes more efficient than apterae, and at other times it was the reverse. Unlike A'Brook, workers such as Evans (1954) in Tanzania, Booker (1963) in northern Nigeria, Davies (1972) in Uganda, and Farrell (1976b) in Malawi all regard alatae as less important than apterae and nymphs as agents of secondary spread of the virus within the crop.

The timing of immigration by A. craccivora and the response of this species to crop age and spacing are two major factors determining the level of primary rosette infection. Secondary spread occurs when adjacent plants are colonized by alatae or

apterae from primary infected source plants. The rate of this secondary spread from inoculated primary sources within the crop varies approximately with crop age, spacing and the number of aphids (alatae, apterae and nymphs) per infected plant.

2.3 Rosette vector, Aphis craccivora Koch

2.3.1 Distribution and host range

Aphis craccivora is virtually cosmopolitan. It is found in Africa, Argentina, Australia, Chile, U.S.A., Central Africa and India. The aphid is polyphagous, although it prefers to feed on the young shoots of leguminous plants. Akinfenwa (1977) reported the occurrence of A. craccivora on over 60 wild and cultivated plant species in ten families in Nigeria. Twenty four of these plants belong to the Papilionaceae. It was found on these host-plants during the rainy season and also in the dry season up to January. A. craccivora has been found to exist on Sesbania sesbans which persists throughout the dry season in lowlying most sites. The aphid is also known to pass the dry season on some irrigated

cultivated crops such as Phaseolus valgaris and on volunteer groundnut seedlings (Booker, 1964).

2.3.2 Classification and morphology

The groundnut rosette virus vector, Aphis craccivora Koch, belongs to the order Homoptera and family Aphididae. It is a plant sucking insect and is commonly called the groundnut or cowpea aphid. A. craccivora, described in 1854 by Koch, has some other synonyms such as A. laburni and A. leguminosae (Theo.) (Storey & Bottomley, 1928; Eastop, 1958).

The aphids are generally small, soft-bodied insects with the body length varying from 1.5 to 2.0mm. They may be winged (alatae) or wingless (apterae). Adults are black or dark brown while nymphs are dark and fairly rounded in body shape. They have a pair of cornicles.

2.3.3 Life history

Reproduction is parthenogentic and viviparous in the tropics, although both sexual and asexual means of reproduction exist in the temperate regions. In Nigeria, except possibly in areas like the Jos and Mambila plateaux, all of the aphids likely to be

encountered are parthenogenetic viviparous alatae or apterae (Misari, per comm.).

The aphids are highly prolific and their numbers can increase rapidly in a relatively short time. The development of one generation takes 6 to 8 days. With each generation (up to nine generations are possible in a good year), the degree of infestation increases 5 to 8 folds. The production of 2 to 3 progeny per day seems to be the rule (Kranz et al., 1977). Alatae produce only about half the progeny produced by apterae and this is probably why alatae are considered by some people as being less important than apterae in the secondary spread of the virus.

2.3.4 Economic importance

The damage caused to crops by aphids is manifold and crop loss is both qualitative and quantitative. They suck the plant sap and inject toxic saliva into the plant tissues during the feeding process. This results in death or malformation of the host-plants or plant parts. The honey dew they excrete is an excellent substrate for soofty mould fungal growth which reduces photosynthetic activity. The exuviae contaminate the vegetable produce thus reducing its quality and market value. During the feeding process,

aphids may also transmit viruses and this is regarded as their most serious damage to crop plants.

A. craccivora transmits the groundnut rosette virus. It also acts as a vector for about 30 other phytopathogenic viruses which can do a lot of damage in other leguminous crops (Kennedy et al., 1961; Kranz et al., 1977).

2.4 Control

The methods used in the control of virus diseases of crop plants vary according to the manner in which the virus is transmitted. Two different control measures have been extensively investigated for use against the groundnut rosette disease. The first is the control of the aphid vector, A. craccivora, by cultural, chemical or biological means. The second is by the use of varieties resistant to the rosette virus itself (Host plant resistance).

2.4.1 Control by cultural means

Various agronomic trials in many parts of Africa have demonstrated the effectiveness of the cultural control of rosette disease by the manipulation of sowing date and plant density. Increase in plant density lessens loss from several virus diseases, for

example, curly top in tomato (Shapovalov et al., 1941), yellow spot in pineapple (Linford, 1945) and yellows in sugar beet (Blencowe and Tinsley, 1951). Early sowing can also decrease losses as shown with yellows in sugar beet (Blencowe and Tinsley, 1951). Broadbent (1964) also demonstrated that, per unit area of cropped land, the number of wheat plants attacked by Cephus cintus decreased with increasing seeding rate. Way et al., (1966) reported that the population of Aphis fabae Scop on field beans decreased with increasing plant density. In constrast to the above findings, Pimentel (1961) found that the number of aphids and other plant-feeding insects increased per unit area of crop with an increase in plant density of Brassica oleraceae L.

Effects of spacing and of sowing date on the incidence of groundnut rosette disease were reported from South Africa (Storey, 1927), Gambia (Hayes, 1932), Ivory Coast (Porteres and Legleu, 1937), Uganda (Storey and Ryland, 1950; Jameson and Thomas, 1954; Davies, 1976), Tanzania (Evans, 1951) and Senegal (Tourte and Fauche, 1954). Groundnuts sown early in the wet season suffer less disease than those sown later (Storey and Ryland, 1950; Cuillemin, 1952;

Sauger et al., 1954; Smartt, 1961; Booker, 1963; A'Brook, 1964; Davies, 1972; Farrell, 1976). In Nigeria, Booker (1963) and A'Brook (1964 and 1968) showed that early planting and close spacing achieved control of rosette disease. Although Soyer (1939), Storey and Ryland (1950), Jameson and Thomas (1954), Real (1956) and A'Brook (1964) obtained some reduction in the number of rosetted plants at high densities, Tourte and Fauche (1956) reported that there was no reduction in the percentage of rosetted plants with increasing plant population. According to A'Brook (1968), the control of rosette disease of groundnuts by early planting and close spacing appeared to be due to the inhibition of the landing response in A. craccivora by the continuous ground cover resulting from the treatments. High plant populations provide an unattractive ground cover for aphids to land. A given number of infective aphids will therefore infest a smaller percentage of plants in a denser planting. Farrell (1976) reported that a settling response was involved in the preference of alatae for wide spacing in young groundnuts. He indicated that early-sown groundnuts escaped early rosette infection through host-evasion in the period prior to the main aphid invasion. But according to Hull (1964),

the fewer aphids observed in closely spaced plants might be associated with the fact that groundnuts grown under close spacing have a different growth pattern compared to those grown under wide spacing. Plants grown under wide spacing are more spread and have their apical buds and young leaves the preferred feeding sites of aphids more exposed. In support of this observation, Davies (1972, 1976) suggested that the higher number of aphids in widely-spaced groundnuts might possibly be due to the availability of more favoured feeding sites. Some other workers (Kennedy and Stroyan, 1959 and Kennedy, 1960) have mentioned that the higher aphid populations in the widely-spaced plants might be due to the alighting response of alatae aphids which is associated with the yellow colour of young and senescent leaves in the wider-spaced plants. Since it is a well-established fact that the alate forms of many species of aphids are attracted to the yellow colour, the wide-spaced plants which expose more young leaves would be more attractive to alatae aphids than would the close-spaced plants. Kennedy et al., (1961) suggested that the checker board effect of earth and widely spaced plants may stimulate the optomotor response of aphids and induce landing.

Way et al., (1966) suggested the following as possible causes of insect numbers decreasing as the density of the host-plant increases:

1. Densely sown crops may be less attractive to colonizing insects in colour or as optomotor stimuli.
2. Colonizing insects may penetrate dense crops less readily.
3. Crowded plants may be less able to retain insects that are attracted to them because they have fewer 'token' or nutritious 'arrestants'.
4. Densely sown plants may be less nutritious for established insects.
5. Higher humidities and low temperatures in dense crops may favour insects less.
6. Natural enemies may be more effective in dense crops.

2.4.2 Chemical control

In general, the aim of using insecticides against aphids is to control the multiplication of the immigrant alates. The insecticides do not entirely protect the crop from primary infection by viruliferous

alate aphids arriving from diseased host-plants elsewhere. A probable reason is that aphids carrying the virus can infect the crop on entry by their first feed before the insecticide takes effect (Misari, personal communication).

Various insecticides have been tried against insect vectors of many virus diseases on a wide range of crops. Granular phorate and dimethoate were reportedly effective against potato aphids and the spread of potato leaf roll virus which they transmit (Burt et al., 1960). Woodford et al., (1983) tried thiofanox 5% granules (Dacamox 5G) on potatoes and found it to be very effective against potato aphids, especially Myzus persicae. Gould and Graham (1969) also tested some insecticides against Aphis fabae Scop on spring sown field beans (Vicia faba L.) and discovered that demeton-methyl 50% E.C., dimethoate 40% E.C. and disulfoton granules (5G and 7.5G) applied as preventive treatments gave effective control of the aphids. Harvey et al. (1979), while controlling wheat curl mite and wheat streak virus, applied two systemic granular insecticides - carbofuran (Furadan 10G) and disulfoton 15G each at the rates of 1.1 and 2.2 kg a.i./ha. at planting time. They observed that carbofuran controlled Eriphytes tulipae Keifer

during the fall, reduced the incidence of wheat streak virus in the spring and resulted in an increase in gain yields. Cypermethrin and carbofuran controlled leafhopper vectors - Nephotetix virescens and N. nigropinctus in India and they subsequently reduced the spread of tungro virus disease in rice crops in that country (Satapathy and Anjaneyulu, 1982).

Like in other crops, various insecticides have also been tested against A. craccivora on groundnuts in Africa, where the rosette virus and its vector occur. Souer (1939) used nicotine emulsions on groundnuts for rosette vector control and concluded that emulsions were not suitable for field use. Panse (1937) reported limited success with a soap and petroleum mixture. More recently, Evans (1954) in Tanzania investigated the use of an organophosphorus compound, schradan, in pot and small field plot trials. He showed that schradan gave good control of aphids and persisted in lethal quantities for 14 to 21 days, but that it was too toxic for general use. Davies and Kasule (1964) and Davies (1965, 1966, 1972, 1975a) in Uganda have subsequently used menazon - an organophosphorus insecticides with good aphicidal qualities and low mammalian toxicity. They found the insecticide to be very effective against the

aphid vector and to consequently decrease the incidence of the rosette disease, leading to improved yield and quality in groundnuts.

In Nigeria, prior to the 1975 rosette epidemic, very little attention was given to research on and use of insecticides against the rosette virus and its vector. After the epidemic, however, an interim recommendation of using Pirimor ULV was suggested for the control of A. craccivora (Rossel, 1977). Later, various insecticides were tried, mostly in glasshouses and in the laboratory. At Mokwa, Rossel (1977), using Menazon seed-dressing dust in pot trials, found it to be effective against A. craccivora for two weeks only, but it reduced the spread of the virus to some extent. At Samaru, disulfoton used both as a seed-dressing (Frumin AL) and as granules (Solvirex) gave good control of both the aphids and the rosette disease (I.A.R., 1978). Abba (1981) conducted a follow-up trial both in the glasshouse and in the field, and also obtained good results with Frumin AL. Iya (1981) also conducted a trial with two granular systemic insecticides - ethiofencarb (Croneton 10G) and carbofuran (Furadan 3G) on the field and found them to be very effective against aphids on groundnuts.

2.4.3 Biological control

Natural enemies have the unique ability of being able to interact with their prey or host populations and to maintain them at lower levels than would otherwise occur. Some are effective at extremely low prey levels but others only at higher levels. It is believed that the control of insects by their natural enemies is a cheap method of crop protection. Many natural enemies have the advantage of being highly host specific.

In India, A. craccivora was effectively controlled by the predatory Menchilus sexamaculatus F. and Coccinella septempunctata L. (Coccinellidae), Xanthogramma scytellare F. (Syrphidae) and Chrysopa cornea Steph (Chrysopidae) (Pater et al., 1976). In Tanzania, however, Evans (1954) felt that natural enemies could not be relied upon unaided on groundnuts because of their varied and unstable populations. Natural enemies, on brussels sprout, notably Syrphidae, proved to be ineffective against Brevicoryne brassicae L. despite advantages given by menazon insecticide and by close spacing (Way et al., 1969). In Nigeria, Booker (1963) recorded many predatory insects (mainly Coccinellidae and Syrphidae) feeding on A. craccivora, but the role they played in reducing aphid populations

on groundnuts was however, not known. Misari (1975) contended that the use of natural enemies for the biological control of insect pests of groundnuts in Nigeria was inadequately researched.

2.4.4 Control by the use of resistant varieties

Host plant resistance as a method of control is directly applied against the virus causing the rosette disease. Rossel (1977) stressed the importance of introducing resistant varieties against the rosette virus as the best long term control method because it is possible to prevent even the primary infection. In Nigeria, none of the local groundnut varieties so far screened has been found to be resistant to the virus. Excellent resistance to or tolerance of the disease exists and was first recognized in Senegal in 1952 after an epidemic of the rosette disease which nearly wiped out a large collection of varieties and selection in Bambey (Sauger et al., 1954). After this discovery, a breeding programme was started at Mokwa in 1962 and it resulted in the production of rosette resistant varieties M25 - 66 and 69-101 ex-Bambey. However, these varieties are long maturing, requiring up to 135 to 140 days on the field, and

were therefore recommended for the riverine areas only. Resistant lines suited for the more arid northern areas (where the bulk of the crop is produced) were identified later in collection and breeding programmes. These lines, RMP 12 and RMP 91, proved to be highly resistant and very productive over many sites in the northern and southern Guinea Savannas (Harkness et al., 1976). Recent screening has shown that lines resistant to the Nigerian green rosette are also resistant to the Nigerian chlorotic rosette and vice-versa (Misari et al., 1980).

2.4.5 Integrated control

Franz (1961) defined integrated control as the integration of cultural, chemical and/or physical methods with the effect of enemies of pests. In 1967, the F.A.O. panel of experts defined it as a pest management system that in the context of the associated environment and the population dynamics of the pest species, utilizes all suitable techniques and methods in as compatible a manner as possible and maintain the pest populations at levels below those causing economic injury.

Integrated pest management is an attainable practice which can yield very good results and success

within the context of a pest management system. Since no single method is usually sufficient to give complete control of both the rosette virus and its aphid vector, A. craccivora, the integrated control approach is therefore urgently needed in this particular situation.

Integrated pest management has been successfully applied in several parts of the world. For example, effective programmes have been set up against citrus pests in Israel, for cotton pests in Peru, for pests of cotton, alfalfa and vineyard in California and for pests in orchards in Central Europe, (F.A.O., 1971). Integrated control of A. craccivora as a vector of groundnut rosette virus in Africa is still being developed.

CHAPTER 3

MATERIALS AND METHODS

1982 Trials

3.1 Land preparation and planting

Two field experiments were conducted at the Institute for Agricultural Research, Ahmadu Bello University, Samaru - Zaria. The fields were mechanically harrowed and single superphosphate fertilizer was incorporated into the soil at the rate of 150 kg/ha before ridging. The ridges were 90 cm apart.

Trial 1 was marked out into four blocks of 10 ridges each 93 m long. The blocks were separated from each other by a metre wide unplanted alley. Each block was then divided into 15 identical plots which were also separated from each other by a metre wide unplanted area. Each plot was 10 ridges each 5 m long. (Fig. 1).

Trial 2 was similarly marked out but each plot was 8 ridges each 5 m long.

Two groundnut varieties, MK 374 and S 38 were used in the trials. They were chosen because they are as susceptible to the rosette virus as some of



Fig. 1. Experimental field layout for trial 1 (1982); figures stand for plant spacing (cm); CFR = carbofuran; CSF = carbosulfan; ETH = Ethiofencarb; PIR Pirimicarb; CON = control.

the local varieties. MK 374 was planted in Trial 1 on the 18th of June at the rate of one seed per stand while S 38 was planted in Trial 2 on the 2nd of July at the rate of two seeds per stand to ensure good establishment.

3.2 Experimental design

The trials were set up with treatments as factorial combinations of three plant spacings (20, 30 and 40 cm) and four insecticides plus an untreated check within rows, laid out in a randomized complete block design with four replications. The arrangement of treatments in both fields was the same.

A. Insecticide treatments

The insecticide treatments were as follows:

1. Granular application of carbofuran (2, 3 - dihydro - 2, 2 - dimethyl benzofuran -7-ylmethylcarbamate), marked as Furadan 3G^{R}, at the rate of 1.0 kg a.i./ha (i.e. 33.3 kg of commercial formulation per hectare).
2. Seed dressing with carbosulfan 5% (2, 3-dihydro 2, 2-dimethyl -7-Benzofuranyl-(dibutylamino) thio-methly carbamate), marketed as Marshall^{R} 5% Dust, at the rate of 1.0 kg powder/100 kg seed.

3. Foliar application of ethiofencarb (2 - ethylthiomethylphenyl methylcarbamate), marketed as 'Croneton^{R} 500 E.C., using low volume spray at the rate of one litre per 500 litre of water/ha.
4. Foliar application of pirimicarb (2 - dimethylamino -5, 6- dimethylphrimidin -4- yl dimethylcarbamate), marketed as Pirimor ED^{R} (50 g/1), as electrodynamic spray (ED) at the rate of one litre per ha.

B. Methods of application

1. Granules- were applied using small envelopes, Seventeen grams of Furadan 3G was applied manually per ridge. This was done by carefully and evenly sprinkling the carbofuran granules in a seed furrow marked out along the crest of each ridge at the time of planting. Each furrow was covered before planting.
2. Seed dressing - 50 gms of the dressing powder was used to dress 5 kg of groundnut seed at the time of planting. This was done by gently shaking the seed and the powder in a polythene bag.

3. Foliar spray- to apply equivalent amount of 1.0 l/ha, 60 mls of Croneton 500 e.c. was mixed with 30 litres of water in a Falcon^{R} sprayer and the mixture was sprayed in Trial 1 on 12 plots each 10 ridges 5 m long. In Trial 2, where each plot was 8 ridges 5 m long, 48 mls was mixed with 24 litres of water for the 12 plots.

4. Electrodyn spray - Pirimor 5% E.D was applied with an Electrodyn^{R} sprayer at the rate of 1.0 l/ha. (i.e. 54.0 and 43.2 mls per spray in trials 1 and 2 respectively).

Foliar applications in both trials started 12 days after planting and continued thereafter at 10-day intervals. Four sprays were applied in each trial and all were done between 7.00 and 8.00 A.m.

An estimate of plant population was made at the start of the trial by counting the number of stands in each plot and missing stands replanted one week after germination.

Each field was weeded by hand three times at 2-week intervals starting from 14 days after crop emergence. At the onset of flowering, each field was remolded with a tractor and cross bonds made at 5 m intervals to conserve moisture and prevent erosion during the period of pod setting.

3.3 Data collection

3.3.1 Aphids and their predators

Starting from one week after seedling emergence, i.e. 12 days after planting, and every two days thereafter, 10 plants were selected at random from the middle four ridges of each plot. The number of aphids on leaves, stems and pegs was counted *in situ* and the aphids were categorized into alates, apterae and nymphs. Observations were also made of the presence of aphid predators (mainly Coccinellidae and Syrphidae) on the same plant as the aphids and the records of their numbers kept for every sampling occasion.

The incidence of rosette virus disease was recorded at weekly intervals starting from 4 weeks after planting until harvest. The number of rosetted plants, location of each and date of symptom appearance for each treatment were recorded.

3.3.2 Yields

The four middle ridges of each plot were harvested on the 25th of October in Trial 1 and on the 2nd of November in Trial 2. Both fields were gleaned thoroughly and pods obtained from each plot were

allowed to dry in properly labelled polythene bags before weighing. The weight of the haulms from each plot was taken after sun-drying for 10 days.

1983 Trial

3.4 Land preparation and planting

The trial was sited at Samaru on field A1 at the Institute for Agricultural Research Agronomy Farm. It was set up with main treatments as factorial combinations of three planting dates (June 8, June 22 and July 6) and four plant spacings (10, 20, 30 and 40 cm) within rows apced at 90 cm apart.

These were laid out in a randomised complete block design replicated three times. Each main plot was split into 5 sub-plots (5 m x 5 ridges each) corresponding to four different insecticide treatments plus an untreated check (Fig. 2).

Groundnut MK 374 was used and all insecticide rates were similar to those of the previous year.

Igran Combi 400 e.c. (pre-emergence herbicide) was applied at the rate of 4.0 l/ha. on the 9th of June. No hand weeding was done throughout the season but a few broad leaf weeds were removed by hand occasionally pulled out. The field was remolded six

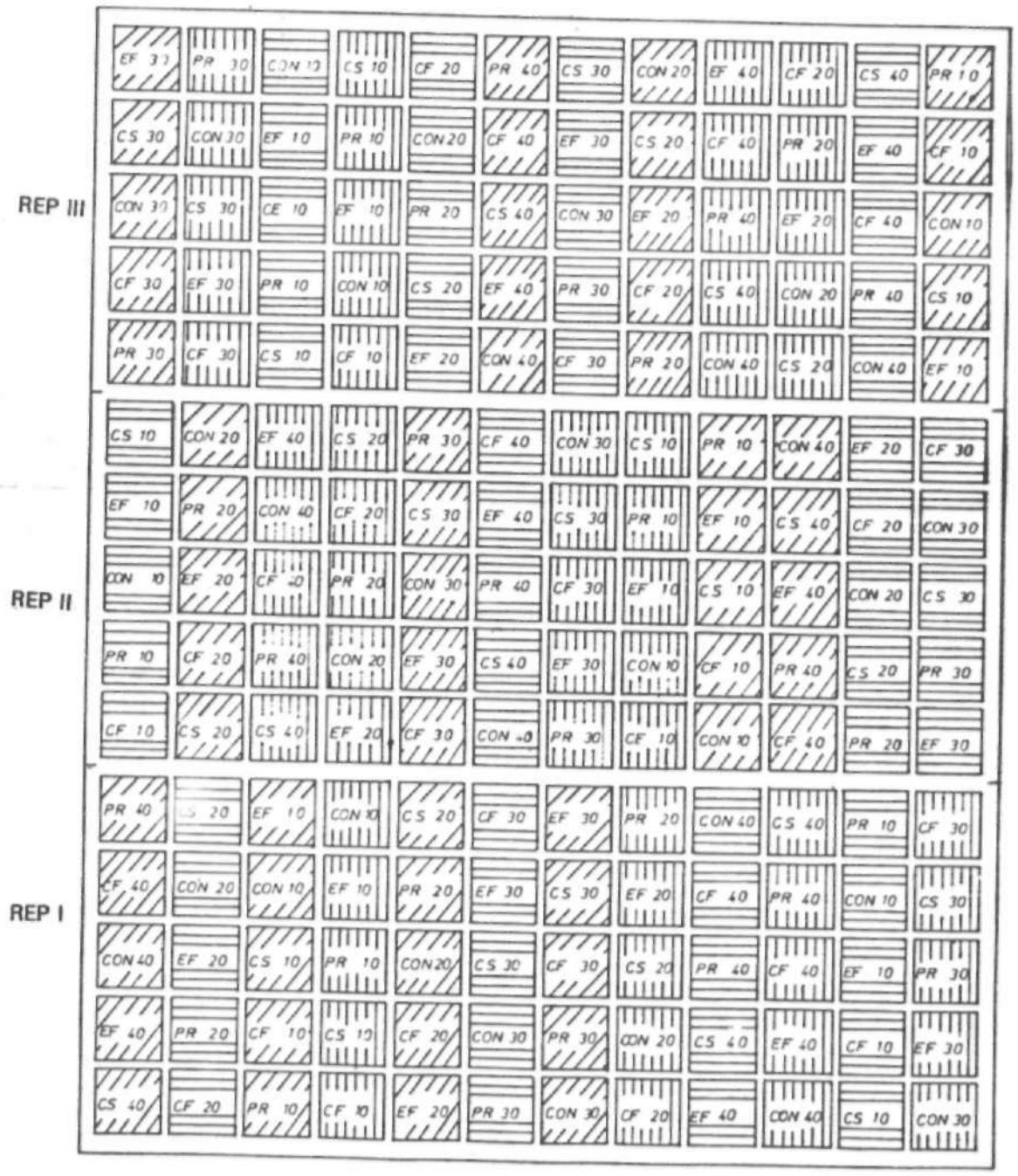


Fig. 2. 1983 Field layout. PR = Pirimicarb, EF = Ethiofencarb, CS = Carbosulfan.
Figures represent spacing in Centimetres |||| = June 8, planting
≡≡≡ = June 22 Planting and /// = June 6 Planting.

weeks after the first planting and cross bonds made at 5 m intervals to conserve moisture and prevent erosion during the period of pod setting.

As in the previous year, all sprays were applied between 7.00 and 8.00 a.m. Also, a 10 m x 1m cloth was used as a drift barrier.

Starting immediately after crop emergence and at 1 to 2-day intervals, alatae, nymphs and apterae of Aphis craccivora and the associated natural enemies were counted in situ on ten randomly selected stands from the central ridges as before. Yello plastic trays containing water were used to trap alate aphids whose numbers were recorded daily starting from 3 weeks after seedling emergence. The traps were kept on cement blocks immediately above crop canopy.

The three middle ridges of each plot were harvested for yield assessment. Weather records, particularly those of rainfall, relative humidity and temperature, were kept throughout the period of the study. The weather records were collected for central weather station at I.A.R., Samaru for both years.

3.5 Supplementary Trials on Chemical control of groundnut rosette vector, Aphis craccivora Koch

3.5.1 Introduction

A supplementary trial using twelve insecticide treatments including untreated control was set up to

determine the efficacy of other insecticides and lower doses of carbofuran in integrated control of groundnut aphids in 1983.

3.5.2 Materials and Methods

The field was hand weeded a day before planting. The twelve treatments were laid out in a completely randomized block design replicated four times. Each plot was 5 m x 5 ridges 0.9 m apart and each surrounded by one metre strip of discard. Groundnut variety 55 - 437 (Ex-Dakar) was used and was planted at a uniform spacing of 30 cm between stands on August 15. Two seeds were sown per stand.

Treatments and methods of application

1. Granular application of chlorpyrifos (O,O-diethyl O - (3, 5, 6 - trichloro -2- pyridyl) phosphorothioate) marketed as Dursban 10G at the rate of 3.0 kg a.i./ha. Using small envelopes, 14 gms of chlorpyrifos granules was applied manually along each 5 m ridge. This was done by carefully and evenly sprinkling the granules in a seed furrow marked out along each ridge - at the time of planting. Each furrow was properly covered before planting.

2. Seed dressing with chlorpyrifos marketed as Dursban 25w at the rate of 600 gms/100 kg seed. Eighteen grams of the dressing powder was used to dress 3 kg groundnut seed at the time of planting.

3. Granular application of carbofuran at different rates and application methods similar to those reported in Chapter 3.2

(a) 1.5 kg a.i./ha. applied at planting.

(b) 2.5 kg a.i./ha; 1.0 kg a.i./ha applied at planting followed by 1.5 kg a.i./ha 40 days later.

(c) 1.75 kg a.i./ha; 0.75 kg a.i./ha applied at planting followed by 1.0 kg a.i./ha 40 days later.

(d) 0.75 kg a.i./ha applied at planting.

(e) 1.0 kg a.i./ha applied at planting.

(f) 0.75 kg a.i./ha applied at planting and chlorpyrifos granules applied at the rate of 1.0 kg a.i./ha 40 days later.

4. Foliar application of pirimicarb using electrodyn sprayer starting 12 days after planting as reported in Chapter 3. Four applications at 10-day intervals were made.

5. Foliar application of cypemethrin/dimethoate (Cymbush Super ED$^{(R)}$) at the rate of 1.0 litre/ha. using an electrodyn sprayer starting 12 days after planting. Four applications at 10-day intervals were made.

6. Seed dressing with carbosulfan at the rate of 1.0 kg powder per 100 kg groundnut seed. The method of application was as reported in Chapter 3.2.

7. Control - untreated.

3.6 Statistical Analysis

Both 1982 and 1983 data were analysed using the variance ratio (f) test.

CHAPTER 4

RESULTS AND DISCUSSION

4.1 Aphid population assessment

4.1.1 1982 Trials

Alate aphids started colonizing the crop 5 to 9 days after crop emergence without regard for spacing or insecticide treatment.

In Trial 1, small colonies of aphid nymphs were seen on a few seedlings of MK 374 starting from 9 days after crop emergence. However, aphid population remained low initially, but increased gradually until 22 days after planting (on 10 July) when a high population of about 12 aphids per stand was attained (Fig. 3). The aphid population then started increasing very rapidly, reaching to a mean peak of 190 aphids per stand at 40 days after planting (on 29 July). The peak period was immediately followed by a period of rapid fall. At 48 days after planting (on 5 August), aphid population had fallen down to an average of 100 aphids per stand. The population remained low with only small fluctuations until 88 days after planting (on 14 September) when no more aphids were observed on the crop.

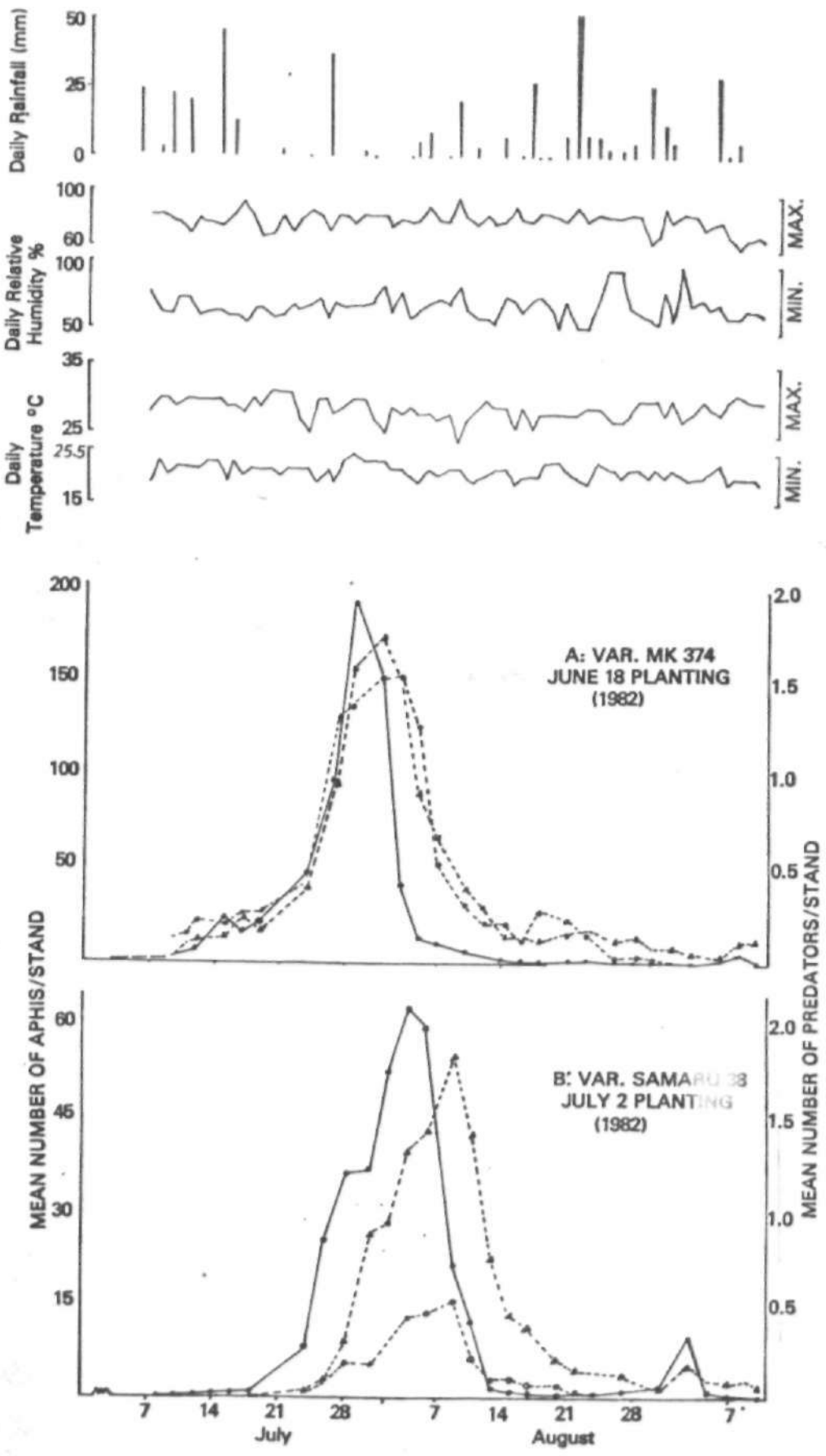


Fig. 3. Seasonal population trend of *Aphis craccivora* (●—●) and its associated natural enemies, Coccinellidae; (▲--▲) and Syrphidae; (○—○) in relation to daily temperature, relative humidity and rainfall (1982).

In Trial 2, immigrant alate aphids started to appear on S 38 within 6 days after the emergence of the crop. At 8 days after crop emergence, small colonies of aphid nymphs were established, but the population remained low until at 15 days after planting (on 17 July) when it started rising very rapidly. A peak of about 65 aphids per stand was reached at 32 days after planting (on 3 August) (Fig. 3). The aphid population then declined very rapidly and at 39 days after planting (on 10 August), the population had fallen to a level of 5 aphids per stand. The population then remained low with only small fluctuations until 70 days after planting when it rose to a second but smaller peak of 12 - 15 aphids per stand. No aphids were seen 71 days after planting (on 11 September) until harvest.

4.1.2 1983 Trials

Immigrant alate aphids were first observed in the field 9 days after the emergence of the crop planted on June 8, (first planting). However, no massive infestation occurred and early multiplication therefore remained low until 36 days after the first planting (on 14 July) when apterous colonies started building up very rapidly. A peak population of 60

to 65 aphids per stand was reached at 54 to 56 days (1 - 3 August) after the first planting i.e. 40 to 42 and 26 to 28 days respectively after the second and the third plantings (Fig. 4). The aphid population then started declining and by 64 days after the first planting (on 11 August), it had come down to an average of 6 aphids per stnad. The population of aphids then started rising again at 68 days (on 15 August) and reached a second, smaller peak of 24 aphids per stand at 78 days after the first planting (on 25 August). The population then declined again and remained low until at 107 days after the first planting (on 23 September) when it attained a third peak with an average of 30 aphids per stnad. The population finally dropped to a very low level at harvest. The rapid increase in the population of aphids as shown in Figs. 3 and 4 occurred between 20 and 40 days after planting.

Figures 3 and 4 show that there was no definite relationship between aphid population and those of temperature, relative humidity and rainfall in both 1982 and 1983. It however, appears from observation that biotic factors and/or interaction with the metereological factors may have some bearing on the population fluctuations.

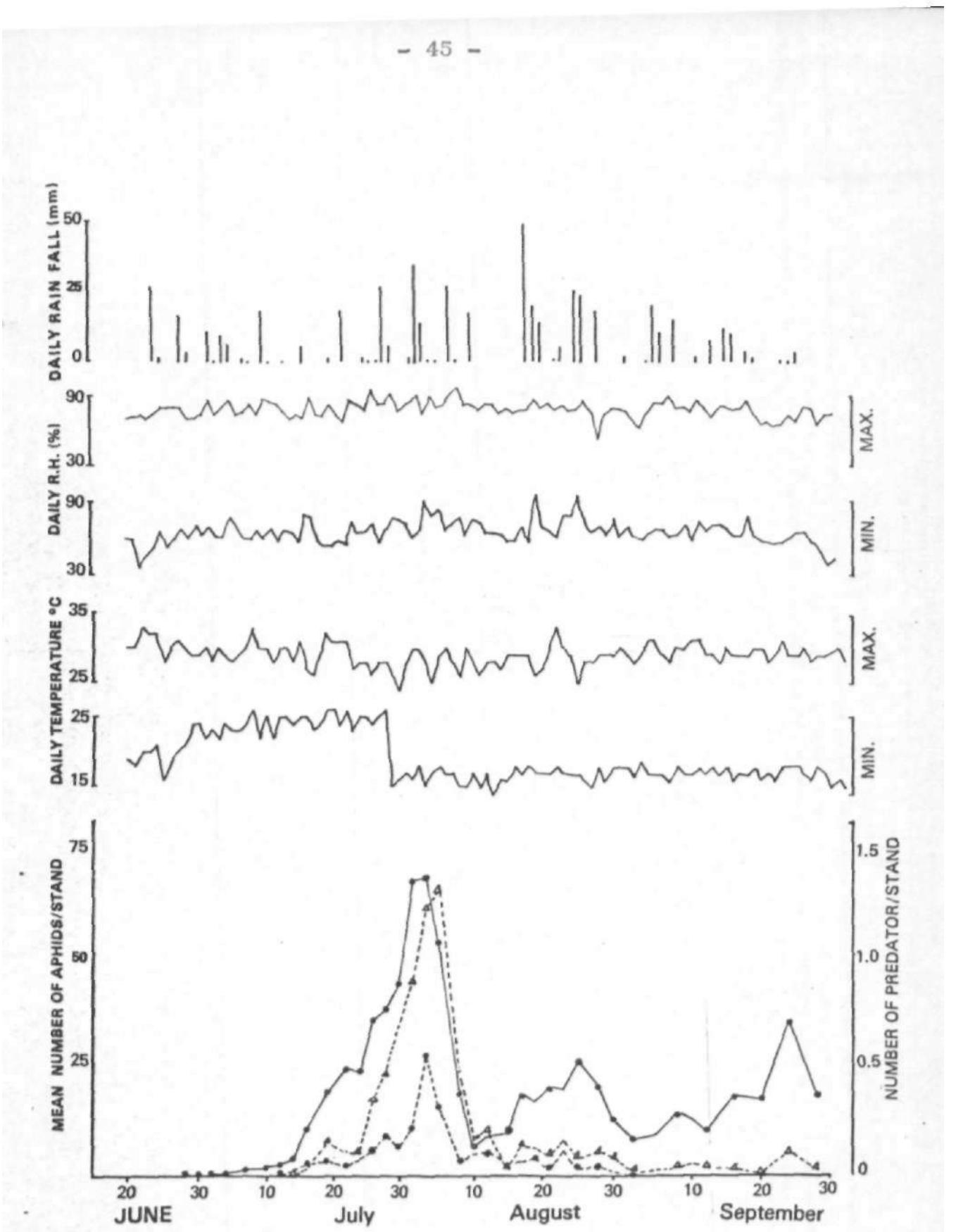


Fig. 4. Seasonal population trend of *Aphis craccivora* (●—●) and its associated natural enemies, Coccinellidae (▲--▲) and Syrphidae (o----o) in relation to daily temperature, relative humidy and rainfall (1983). Groundnut Variety MK 374.

4.2 Natural enemies

The trend in the population of predators (Coccinellidae and Syrphidae) closely followed that of the aphids (Figs. 3 and 4). Cheilomenes sulphurea (Oliv.), C. vicina (Muls.), Exochomus flavipes (Thunb.) and Scymnus sp. (Coleoptera: Coccinellidae) and Paragus borbonicus (Macq.) and Xanthogramma aegypticum (Wied.) (Diptera: Syrphidae) were the most common aphid natural enemies seen. However, the role they played in reducing aphid population was insignificant due to the high ratio of aphids to natural enemies.

In 1982, the population of coccinellid adults and larvae and syrphid larvae in Trial 1 lagged about 3 to 4 days behind that of the aphids. Their population remained at a low level of 0.3 to 0.5 per stand until 30 days after planting when the population of aphids started rising very rapidly. The population of natural enemies reached a peak of 4.7 - 5.0 per stand, 43 to 45 days after planting, i.e. 3 to 5 days after aphids had reached their peak (1 - 3 August). Their population then declined but at a slower rate than that of the aphid host (Fig. 3). Unlike in Trial 1 where coccinellids and syrphids populations were about the same, in Trial 2 more coccinellids were seen than

syrphids. The population of natural enemies started building up 7 days later than that of the aphids and reached a peak of 2 - 3 per stand 5 days after that of the aphids (Fig. 3).

In the 1983 trial, there were also more coccinellids than syrphids and the populations of both groups of natural enemies started building up 10 days later than that of the aphids. Their population continued rising until a peak of about 2 per stand was reached 56 to 58 days after the first planting, i.e. 2 to 4 days after the aphids had reached their peak (3 - 5 August). Like the aphid population, the population of natural enemies similarly declined rapidly after the peak period and by 64 days after the first planting, (i.e. 50 and 36 days after the second and the third plantings), the population of natural enemies had come down to a level of 0.2 per stand (Fig. 4). At harvest, only adult coccinellid beetles were seen in the field.

4.3 The effect of plant spacing on aphid numbers

4.3.1 1982 Trials

In Trial 1 in which MK 374 was planted, there were significantly fewer aphids in the 20 cm spacing

(P < 0.05), than in the 30 and 40 cm spacings. The difference between the 30 and 40 cm spacings was not statistically significant (Table 1). In Trial 2 which had S 38, the differences in aphid numbers between the three spacings were small and statistically insignificant (Table 1).

4.3.2 1983 Trials

Table 2 shows that the population of the aphids was inversely related to plant density since more aphids were recorded in the plots with wider spacing than in those with close-spacing. An analysis of variance of the data showed that there were significcantly fewer alates in the 10 and 20 cm spacings (P < 0.05) than in the 30 and 40 cm spacings. The differences in alate numbers between the 10 and 20 cm and between the 30 and 40 cm spacings were not statistically significant.

The effect of spacing on the number of apterae is shown in Table 2. There were significantly fewer apterous adults (P < 0.05) and nymphs (P < 0.05). in the 10 and 20 cm spacings than in the 40 cm spacing. The difference between the 10 and 20 cm spacings and between the 20 and 30 cm spacings was insignificant, but that between the 30 and 40 cm spacings was.

Table 1. Effect of Plant Spacing on the Incidence of Aphis craccivora (1982).

Plant Spacing (cm)	Mean No. of aphids/stand	
	MK 374	S 38
20	128.40	5.15
30	164.30	5.08
40	169.40	5.59
F value	11.76	n.s
LSD (P=0.05)	18.61	-

n.s = non significant (P=0.05).

Table 2. Effect of Plant Spacing on the Incidence of Aphis craccivora (1983).

Plant Spacing (cm)	Mean No. of aphids/stand			
	Alatae	Apterae	Nymphs	Total
10	0.06	0.52	5.40	5.98
20	0.08	0.97	9.60	10.65
30	0.12	1.31	12.60	14.03
40	0.12	2.18	22.00	24.30
F value	4.11	10.89	8.84	8.76
LSD (P=0.05)	0.04	0.63	7.00	7.70

The overall effect of plant spacing on aphid incidence is summarized in Table 2. An analysis of variance of the data showed that the 40 cm spacing had significantly more aphids ($P < 0.05$) than all the other spacings. The difference in aphid numbers between the 10 and 30 cm spacings was also significant, but that between the 10 and 20 cm spacings was not.

Figure 5 shows the effect of plant spacing on the population of aphids on three planting dates. At the early period, i.e. 7 to 10 days after crop emergence, more apterous aphid colonies were found in the 10 and 20 cm spacings. At 20 to 25 days after planting, when very good ground cover had been achieved in the 10 and 20 cm spacings and aphid colonies started increasing very rapidly, the effect of spacing on the population of aphids became pronounced. By 36 to 53 days after the emergence of the June 8 planting, the aphid populations in the 30 and 40 cm spacings were very much higher than those in the 10 and 20 cm plantings. By 32 to 45 days after the emergence of the June 22 planting, plots planted at 30 and 40 cm spacings also had many more aphids than the 10 and 20 cm spacings. In the July 6 planting, there were more aphids in the 30 and 40 cm spacings than in the

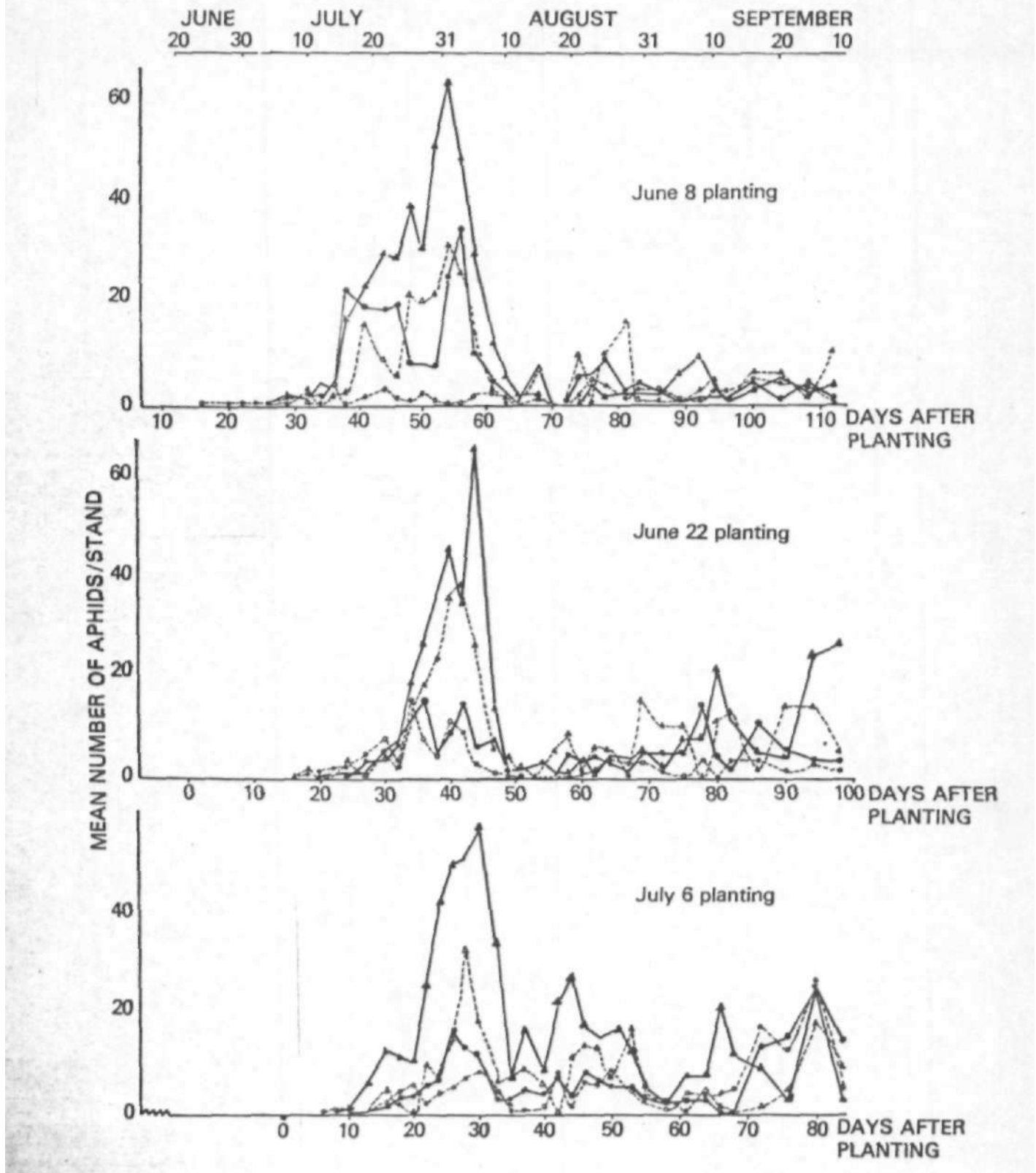


Fig. 5. Seasonal population trend of *Aphis craccivora* on groundnut as affected by plant spacing at three planting dates ((1983),, o–o=10 cm;●–●= 20 cm; ▲–▲ = 40 cm spacings.

10 and 20 cm spacings. However, in the two June plantings, there were only small differences in aphid numbers between the four spacings beyond the peak period (Fig. 5).

From results obtained, alates did not show any differential colonization of the different crop densities during the first three weeks of planting since no significant differences in numbers were observed at various plant densities during this period. However, from the third to the sixth weeks when immigrant alatae started arriving in fairly large numbers (both *in situ* and in yellow traps), aphids exhibited some preferential colonization of open-spaced groundnuts since more aphids (both alatae and apterae) were observed in them. There was a very rapid increase in aphid population during this period and it should therefore be regarded as the most important period in relation to crop growth and secondary spread of rosette disease - especially if the aphids are viruliferous. Because of this preference for conolizing wide-spaced groundnuts after the first three weeks of planting, higher numbers of both numphs and adult apterae were recorded in wider-spaced compared to closely-spaced groundnuts.

Kennedy, Booth and Karshaw (1961) suggest that the chequerboard effect of bare earth and crop cover in widely spaced plants may stimulate the optomotor response and induce landing of immigrant alatae in low plant density areas. Further investigations by Hull (1964) showed that the effect of spacing resulting in the higher number of A. craccivora in wide spaced plants was due to the fact that a larger number of alatae landed on widely spaced groundnuts because a greater area of young yellow leaves were exposed and the effect was therefore due to colour attraction. The different nutritional status of the groundnut plants at different densities (Yayock, 1977) may also have been responsible for the difference of aphid population.

The present results show that there was an interaction between plant spacing and aphid numbers before alates started colonizing the crop. The continuous vegetative groundcover provided by the closely-spaced crop during the first three weeks of planting prevented landing by alates and also resulted in fewer aptera and nymphs.

Yellow trap counts show that higher numbers of alatae were trapped in widely spaced plants (Fig. 6).

4.4 The effect of planting date on aphid numbers

Table 3 shows the effect of planting date on the number of aphids. The number of alatae from colonies in the July 6 planting was significantly more ($P < 0.05$) than those found in the June 8 and June 22 plantings which were statistically similar. An analysis of variance showed that planting date did not significantly affect the number of apterae and nymphs. Although Table 3 shows that the total number of aphids increased with a delay in planting time, the overall effect of planting date on aphid numbers was very small and statistically not significant. However, figure 5 shows that aphids started colonizing the groundnut crop as early as 9 days after emergence of the June 8 crop but the population remained low until at 26 days after planting. Aphid population was also low until at 20 and 10 days after planting in the June 22 and July 6 plantings, respectively. Aphid numbers in the June 8 planting reached a peak at 56 to 58 days after planting while the later plantings attained peak populations much earlier (42 - 44 days after planting in June 22; 28 - 30 days after planting for the July 6 planting). This trend is also reflected in the rate of population increase. The periods of high aphid population build (Fig. 5) are

Table 3. Effect of Planting Date on the Incidence of Aphid craccivora (1983).

Planting date	Mean No. of aphids/stand			
	Alatae	Apterae	Nymphs	Total
June 8	0.07	1.13	10.50	11.70
June 22	0.09	1.17	11.70	12.96
June 6	0.13	1.54	15.00	16.67
F value	9.29	n.s	n.s	n.s
LSD (P=0.05)	0.03	-	-	-

n.s = non significant (P=0.05).

most likely to coincide with periods of fast secondary spread disease.

Yellow trap counts show that higher numbers of alatae were trapped in late planted crop (Fig. 6).

The present study shows that groundnuts planted on July 6 supported more A. craccivora (alatae, apterae and nymphs) than those planted on June 8 and 22. However, irrespective of planting date, peak populations of A. craccivora usually occurred between the last week of July and the first week of August. This therefore indicates that peak populations will be reached on lated planted groundnuts at an earlier phenological stage than that of earlier crops. If the aphids are viruliferous, the incidence of rosette virus will thus be expected to be higher in the late crop. According to A'Brook (1963), Booker (1964) and Farrell (1976), the fewer aphids in early planted groundnuts was due to the fact that these plants were physiologically mature and covered more ground prior to the main aphid invasion and were therefore able to escape early aphid invasion through non-preference manifested through the landing and/or seetling responses of the aphid. This shows that aphid infestation is a function of crop age and spacing.

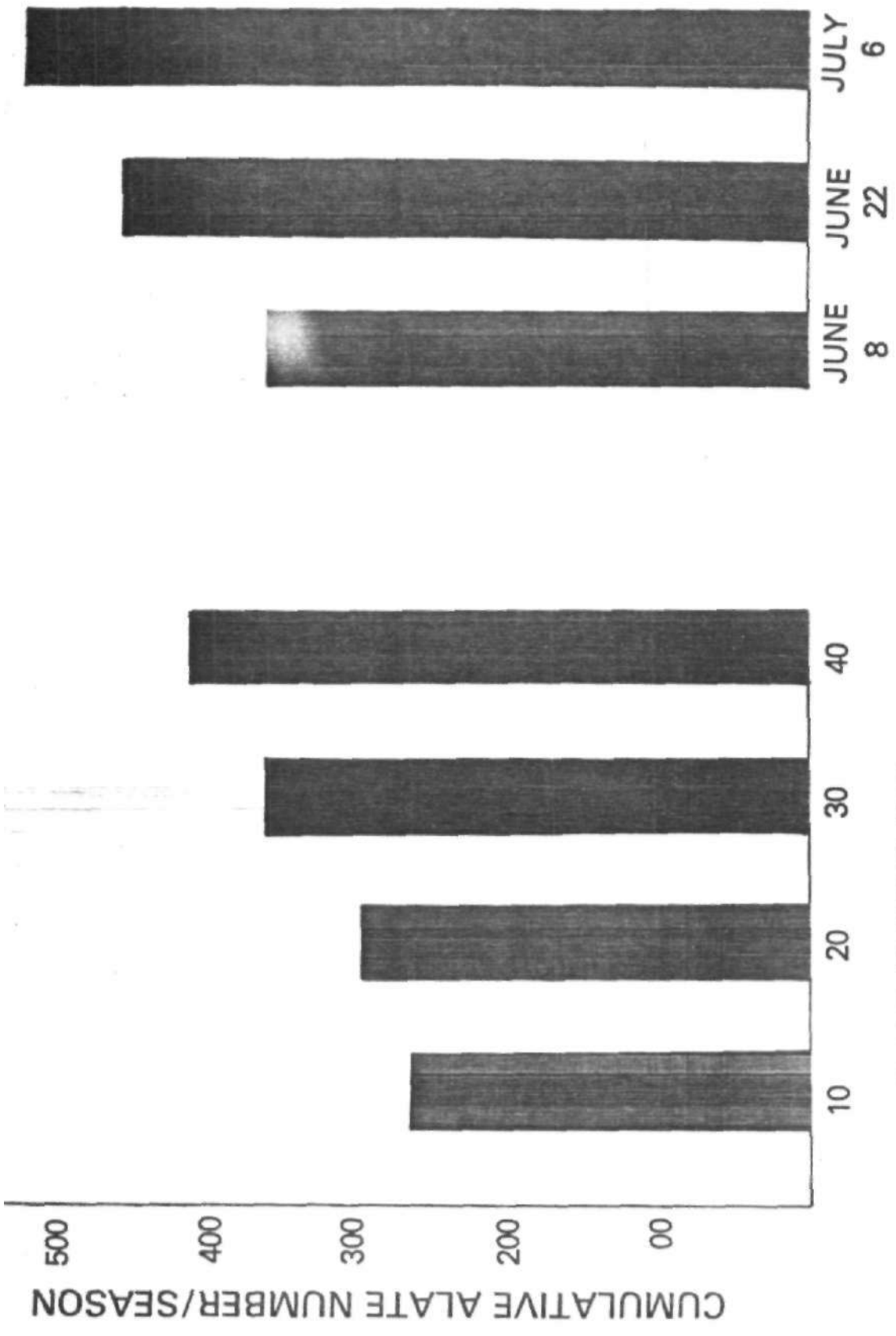


Fig. 6. Number of alatae of *Aphis craccivora* trapped in yellow water trays in relation to plant spacing and planting date (1983)

4.5 The effect of insecticides on aphid numbers

4.5.1 1982 Trials

In the two trials conducted, all insecticides significantly reduced aphid numbers compared with the controls ($P \leq 0.05$) for both Trials 1 and 2). Also in both trials, carbofuran gave the best control. Ethiofencarb was statistically better than pirimicarb and carbosulfan (Table 4A).

Figures 7, 8 and 9 show that carbofuran applied at the rate of 1.0 kg a.i./ha at planting time gave excellent control of the aphids for up to 30 to 35 days after planting. In all the plots treated with carbofuran, the aphid population was kept very low throughout the season. Carbosulfan applied at the rate of 1.0 kg of the dust to 100 kg groundnut seed at planting was effective for 10 to 12 days only. Each application of ethiofencarb at the rate of 0.5 kg a.i./ha protected the groundnut crop from attack by aphids for 8 to 10 days and the four applications given at 10-day intervals prevented any aphid colony formations throughout the season. Ethiofencarb was observed to have very effective killing action immediately after application. While carbofuran and ethiofencarb could protect the groundnut against

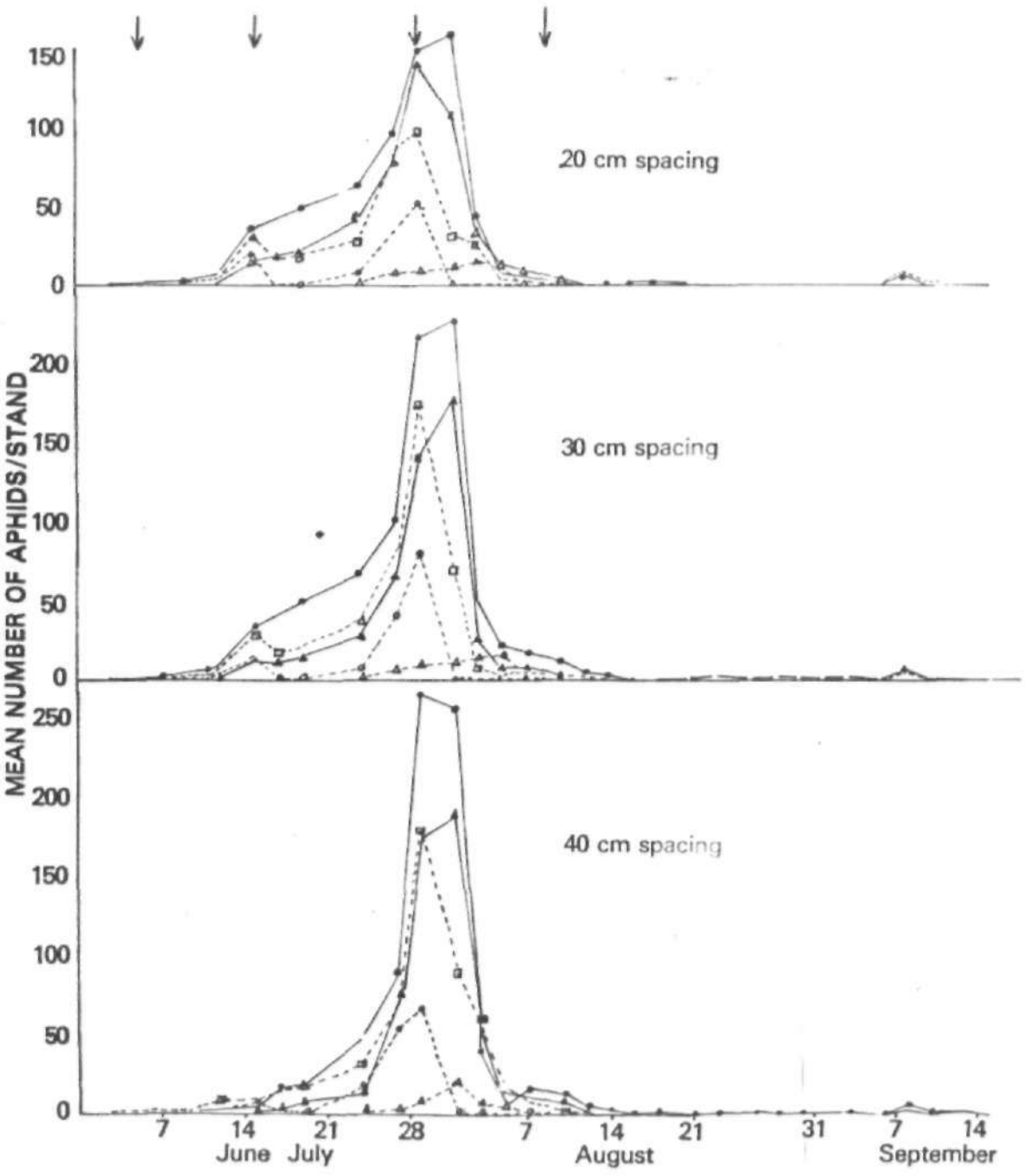


Fig. 7. Seasonal population trend of *Aphis craccivora* as affected by insecticide application on groundnuts (MK 374) planted at three plant spacings planted June 18, 1982); ●—● = Control; ○—○ = Ethiofencarb; ▲—▲ = Carbosulfan; △- - -△ = Carbofuran; □- - -□ = Pirimicarb; ↓ = Application dates of Ethiofencarb and Pirimicarb.

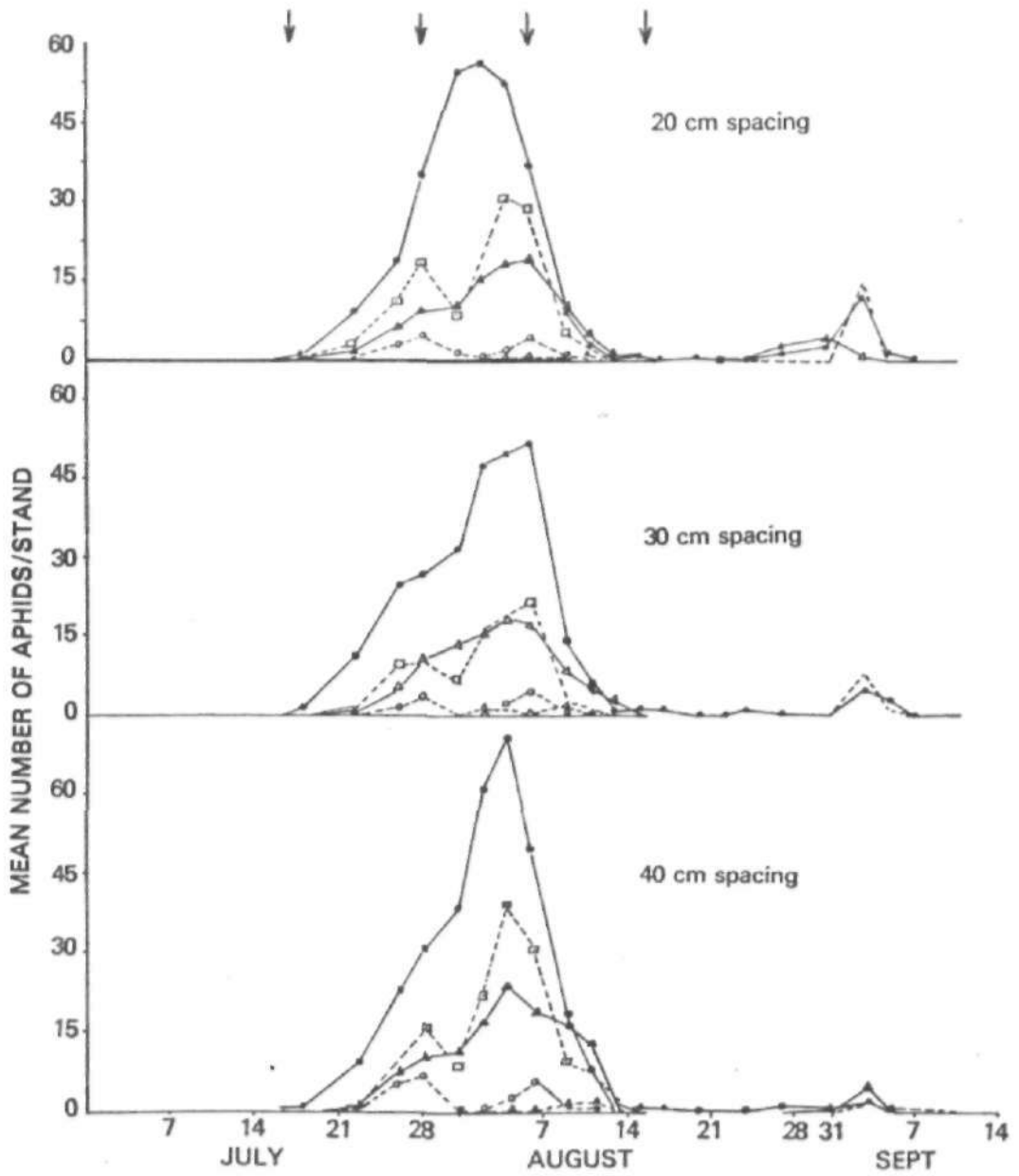


Fig. 8. Seasonal population trend of *Aphis craccivora* as affected by insecticides application on groundnuts (S38) planted at three plant spacings (planted July 2, 1982); ●—● = Control; o--o = Ethiofencarb; ▲—▲ = Carbosulfan; ▲---▲ = Carbofuran □--□ = Pirimicarb; ↓ = Application dates of Ethiofencarb and Pirimicarb.

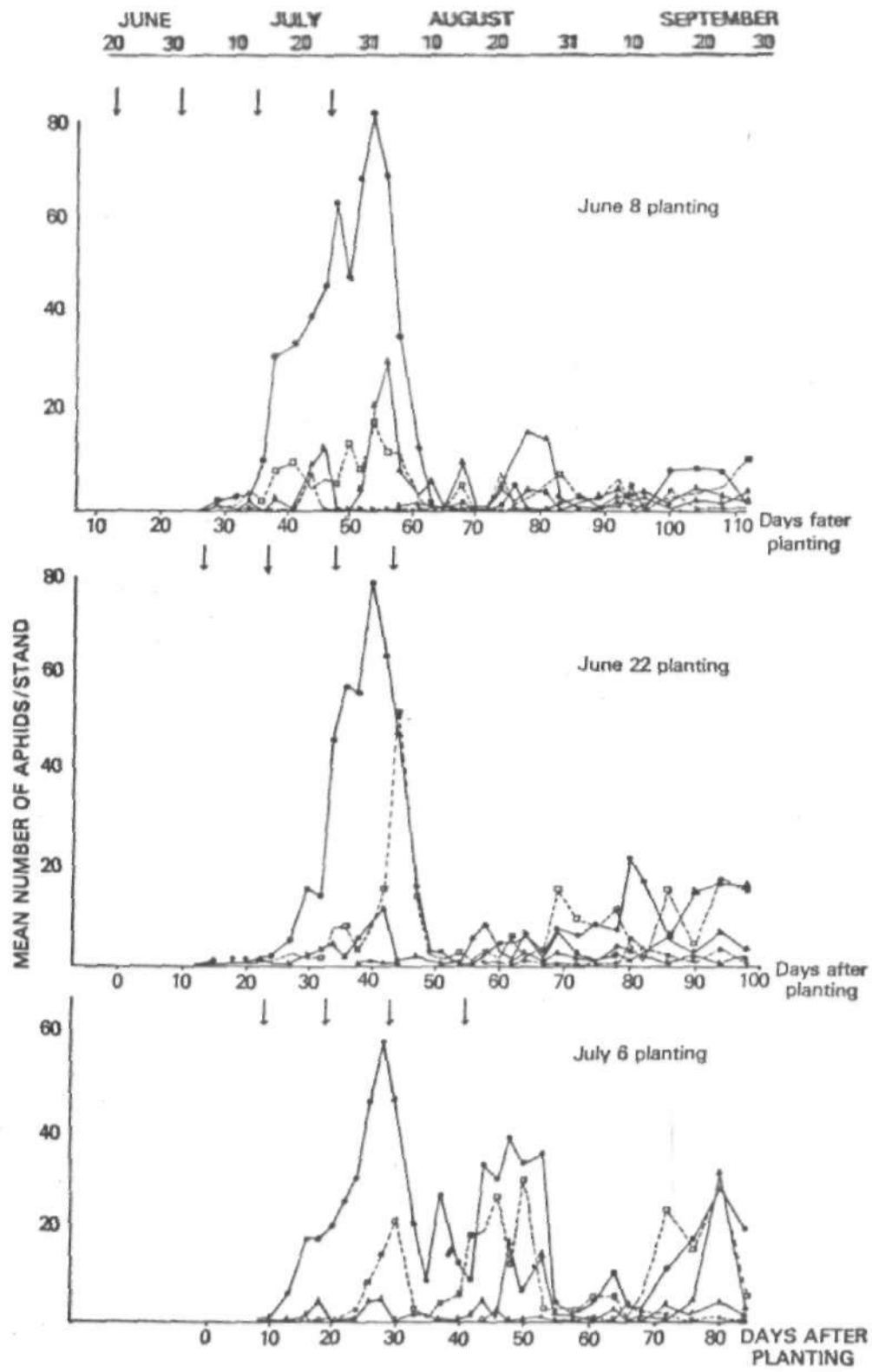


Fig. 9. Seasonal population trend of *Aphis craccivora* following application of insecticides on g'nuts (MK 374) at three planting dates;
●—● = control; ○—○ = Ethiofencarb; ▲—▲ = Carbosulfan;
Δ—Δ=Carbofuran; □ = Pirimicarb; ↓ = Application dates of Ethiofencarb and Pirimicarb.

secondary spread, carbosulfan may not be as effective because the groundnut will still remain at a vulnerable stage when the insecticide will have lost its potency. Pirimicarb was apparently ineffective since aphids were found in treated plots even at one day after application. This means that if the aphids were viruliferous they could still have transmitted the virus and thereby spread the disease.

4.5.2 1983 Trials

The population of aphid morphs (alatae, adult apterae and nymphs) in untreated control plots was significantly higher ($P < 0.05$) than that in treated plots (Table 4B). Among treated plots, there were significantly fewer alates in plots treated with ethiofencarb and carbofuran than in those treated with carbosulfan. There was no statistical difference between pirimicarb and carbosulfan treated plots. Apterae population in treated plots showed that there were significantly more apterae in plots treated with carbosulfan than in those treated with ethiofencarb, carbofuran and pirimicarb. There was statistical difference between pirimicarb and ethiofencarb treated plots but that between carbofuran and pirimicarb treated plots was not. There were also significantly

Table 4. Effect of Insecticides on the Incidence of Aphis craccivora on groundnut (Vars. MK 374 and S 38).

A. 1982 Trials

Treatment	Mean No. of aphids/stand	
	MK 374	S 38
Pirimicarb	185.70	6.90
Ethiofencarb	64.80	2.80
Carbosulfan	202.90	5.90
Carbofuran	20.20	1.10
Control	295.80	100.60
F value	174.97	99.56
LSD (P=0.05)	24.00	1.00

Table 4.

B. 1983 Trials

Treatment	Mean No. of aphids/stand			
	Alatae	Apterae	Nymphs	Total
Pirimicarb	0.08	0.76	7.70	8.54
Ethiofencarb	0.03	0.10	0.90	1.03
Carbosulfan	0.12	1.54	13.70	15.36
Carbofuran	0.04	0.23	1.70	1.97
Control	0.21	3.60	38.00	41.81
F value	10.76	48.40	45.40	45.74
LSD (P=0.05)	0.06	0.57	6.30	6.80

more nymphs in plots treated with pirimicarb and carbosulfan than in those treated with ethiofencarb. Carbofuran performed significantly better than carbosulfan, but not pirimicarb. There was no statistical difference between ethiofencarb and carbofuran treated plots.

Figure 9 shows that carbofuran completely prevented the formation of aphid colonies for up to 58 to 70 days in the June 8 planting. It gave excellent control for up to 62 days in the June 22 planting and up to 45 days in the July 6 planting. Ethiofencarb completely prevented the formation of aphid colonies for 8 to 10 days after application. The four applications of ethiofencarb gave excellent control of the aphids for up to 60 days after planting. Carbosulfan effectively prevented the development of early aphid colonies during the first 10 to 15 days after planting.

Out of the four insecticides tried for two years, carbofuran applied at the rate of 1 kg a.i./ha at planting time and ethiofencarb, applied at 0.5 kg a.i./ha at 10 day intervals commencing 10 days from emergence of the seedlings, gave promising control of A. craccivora on groundnuts. The most effective treatment was undoubedly carbofuran which gave

excellent control of A. craccivora for 35 to 40 days after planting thus protecting the crop from severe infection during the period. Pirimicarb and carbosulfan were not very promising with regard to aphids control at the rates applied. Pirimicarb was found to be effective for only 2 to 3 days after its application while carbosulfan dust was found to be effective for only 10 - 12 days after planting. This shows that both pirimicarb and carbosulfan can not effectively prevent secondary spread of the disease because they did not give good control of the aphids in the field. However, these pesticides may possibly offer better control of aphids if applied at higher rates, in which case the economics of control must be taken in to consideration.

Carbofuran and ethiofencarb proved effective in preventing the build-up of large populations of aphids and can therefore help to reduce secondary spread of the rosette disease. However, none of the insecticides tested has completely prevented primary rosette infection because some viruliferous alatae invariably fed and transmitted the disease before being killed by the insecticides. Similar work conducted by Davies (1972) showed that the systemic

effect of Menazon insecticide could persist long enough to reduce aphid reproduction and hence limit secondary spread of the virus within the crop.

4.6 The effects of interactions between plant spacing, planting date and insecticides on aphid numbers

4.6.1 Planting date x plant spacing

Appendix 1A shows that there were significantly more alatae on plants spaced at 40 cm apart and planted on 6 July ($P < 0.05$), than on closely-spaced groundnuts planted at an earlier date. The 30 cm spaced groundnuts planted on June 22 or July 6 had significantly ($P < 0.05$) more alatae than the 10 and 20 cm spaced groundnuts planted on June 8 or June 22. Planting on June 8 or 22 did not show any significant interaction with spacing even though fewer alataes were recorded on the 10 and 20 cm spaced groundnuts. Also, there was no significant relationship between plant spacing and planting date on the number of apterae and nymphs (Appendix 1B and C). There was however an increase in the number of apterae and nymphs with delay in planting date and increase in plant spacing. The overall effect of interactions between plant spacing and planting date on the total number of aphids was not significant (Appendix 2).

4.6.2 Planting date x insecticides

Appendix 3A shows that there was no significant difference in number alates between treated and untreated plots that were planted on June 8. In the crop planted on June 22, control plots contained significantly more alatae ($P < 0.05$) than carbofuran, ethiofencarb and pirimicarb plots which were statistically similar. Observations between carbosulfan and control plots planted on June 22 was not significant. In the July 6 planting, control plots had significnalty more alatae ($P < 0.05$) than carbofuran, pirimicarb and carbosulfan plots and the latter contained significantly more alatae than ethiofencarb plots. Carbofuran did not perform better than pirimicarb in the July 6 planting. It however gave significantly better control of aphids than carbosulfan which was statistically similar to pirimicarb. The effect of the interaction between planting date and insecticides on the number of apterae and nymphs (Appendix 3B and C) was not significant.

4.6.3 Plant spacing x insecticides

Analysis of the 1982 data from Trial 1 showed that there were significantly more aphids in the control plots planted at 30 and 40 cm spacing

($P < 0.05$) than all other plots. The lowest number of aphids was observed in carbofuran and ethiofencarb plots, irrespective of plant spacing and the difference between them was not significant. Both carbofuran and ethiofencarb at the different spacings performed significantly better than pirimicarb and carbosulfan (Appendix 4A).

The interaction between plant spacing and insecticides on aphid numbers in Trial 2 (1982) was not significant (Appendix 4B).

Appendix 5 shows the effect of interaction between plant spacing and insecticides on the number of alatae, apterae and nymphs in the 1983 trials. Control plots planted at 40 cm spacing contained significantly more apterae and nymphs ($P < 0.05$) than all the treated plots planted at 10, 20, 30 and 40 cm spacings and control plots planted at 10, 20 and 30 cm spacings. The effect of the interaction between plant spacing and insecticides on the number of alatae was not significant. There was also no significant difference between ethiofencarb and carbosulfan plots at 10 and 20 cm spacings.

Appendix 6 shows that in the 10 cm spacing, the difference in the number of aphids between control and treated plots was not significant. In the 20 cm

spacing, control plots contained significantly more aphids ($P < 0.05$) than ethiofencarb, carbofuran and pirimicarb plots which were statistically similar. The difference between control and carbosulfan plots was also not significant. In the 30 cm spacing, control plots contained significantly more aphids ($P < 0.5$) than treated plots. Among the latter, ethiofencarb plots contained significantly fewer aphids than carbosulfan plots only. The difference between ethiofencarb, carbofuran and pirimicarb was not significant. In the 40 cm spacing, control plots contained significantly more aphids ($P < 0.05$) than treated plots. In the latter, carbosulfan plots contained significantly more aphids than ethiofencarb, carbofuran pirimicarb plots which were statistically similar.

4.7 The effect of plant spacing on the population of natural enemies

4.7.1 1982 Trials

In the two trials conducted, the 30 and 40 cm spacings had significantly more coccinellid adults and larvae ($P < 0.05$) for Trial 1 and ($P < 0.05$) for Trial 2) than the 20 cm spacing. Spacing had no significant effect on the number of syrphid larvae (Table 5).

Table 5. Effects of Plant Spacing and Insecticides on the incidence of Aphis craccivora predators (1982).

Treatment	Mean No. of predators per stand			
	Coccinellids[a]		Syrphids[b]	
Plant Spacing (cm)	MK374	S38	MK374	S38
20	1.16	0.08	1.24	0.32
30	1.29	0.00	1.36	0.33
40	1.45	0.98	1.42	0.30
F value	0.13	2.72	n.s	n.s
LSD (P=0.05)	0.24	0.17	-	-
Insecticides				
Pirimicarb	1.45	1.23	1.82	0.40
Ethiofencarb	0.50	0.41	0.53	0.12
Carbosulfan	1.75	1.10	1.79	0.35
Carbofuran	0.27	0.33	0.15	0.11
Control	2.53	1.50	2.73	0.57
F value	75.27	43.97	75.94	37.95
LSD (P=0.05)	0.30	0.23	0.34	0.12

[a] Both adult and larval populations were recorded.

[b] Only larval populations were recorded.

4.7.2 1983 Trials

The 40 cm spacing contained significantly more natural enemies (both Coccinellidae and Syrphidae) ($P < 0.05$) than the 30 cm spacing which also contained significantly more natural enemies than the 10 cm spacing. The number of natural enemies between the other spacings (i.e. 10 and 20; 20 and 30) was not significantly different (Table 6).

These results show that the population of natural enemies increased with a decrease in plant density. Since the aphid population was found to increase with a decrease in plant density, the data obtained therefore indicate that the higher the population of aphids in the field, the higher would be the population of natural enemies. However, because the ratio of natural enemies to aphids was very high and stood at about 1:60 (Tables 1 - 6 and Figs. 3 and 4), the natural enemies could not, on their own, effectively control the aphids.

4.8 The effect of planting date on the population of natural enemies

Table 6 also shows that planting date had no significant effect on the number of natural enemies.

Table 6. Effects of Plant Spacing, planting date and insecticides on number of Coccinellidae and Syrphidae, predators of Aphis craccivora (1983).

Treatment	Predators[a/] stand
Plant Spacing (cm)	
10	0.08
20	0.17
30	0.25
40	0.48
F value	10.31
LSD (P=0.05)	0.16
Planting date	
June 8	0.27
June 22	0.25
July 6	0.22
F value	n.s
LSD (P=0,05)	-
Insecticides	
Pirimicarb	0.12
Ethiofencarb	0.01
Carbosulfan	0.26
Carbofuran	0.01
Control	0.81
F value	58.30
LSD (P=0.05)	0.12

a/ Includes both coccinellid adults and larvae, and syrphid larvae.

4.9 The effect of insecticides on the population of natural enemies

4.9.1 1982 Trials

In Trial 1 where MK 374 was planted, there were significantly fewer coccinellid adults and larvae ($P < 0.05$) and syrphid larvae in carbofuran - treated plots ($P < 0.05$) than in ethiofencarb - treated plots (Table 5). The latter had significantly fewer natural enemies than the pirimicarb and carbosulfan treated plots. The untreated control plots had the highest number of natural enemies. In Trial 2 where S 38 was planted, there were significantly fewer coccinellids in the carbofuran and ethiofencarb treated plots ($P < 0.05$) than in carbosulfan and pirimicarb treated plots (Table 5). The latter contained significantly fewer coccinellids than control plots. There were significantly fewer syrphid larvae in carbofuran and ethiofencarb treated plots than in carbosulfan plots. The latter contained significantly fewer syrphid larvae than pirimicarb treated plots. Control plots had the highest number of natural enemies.

4.9.2 1983 Trials

There were significantly more natural enemies in untreated control plots ($P < 0.05$) than in plots

treated with insecticides (Table 6). Among those treated, carbosulfan plots contained significantly more natural enemies than plots treated with ethiofencarb, carbofuran and pirimicarb which were statistically similar.

4.10 The effects of interactions between plant spacing, planting date and insecticides on the population of natural enemies

The number of natural enemies in the different plant spacings was not significantly affected by planting date (Appendix 7). Control plots in the 40 cm spacing contained significantly more natural enemies($P < 0.05$) than control plots in the 30 cm spacing (Appendix 8). The latter contained significantly more natural enemies than control plots in the 10 and 20 cm spacings. The lowest populations of natural enemies were observed in the carbofuran and ethiofencarb plots having 10 and 20 cm spacings. However, results obtained (Tables 5 and 6) suggest that of all the insecticides tested, carbosulfan is more selective in favour of the natural enemies than the other products.

4.11 The effect of plant spacing, planting date and insecticides on the incidence of rosette disease

In both 1982 and 1983, the incidence of rosette disease was low and variable. The rosetted plants occurred randomly in the field either singly or in patches (Figs. 10 and 11). However, there were fewer rosetted plants in the 10 and 20 cm spacings than in the 30 and 40 cm spacings (Fig. 12). Although higher rosette incidence was expected with subsequent (latter) planting dates, the reverse was recorded (Fig. 13). This may be due to early invasion of control plots in the earlier planted groundnuts by viruliferous aphids and because insecticides were applied in the surrounding plots multiplication and spread of the infective aphids was restricted to only those earlier planted control and carbosulfan treated plots. Also, this may have been due partly to the generally low rosette incidence during the season, possibly as a result of later invasion by non-viruliferous alatae. The data also showed that fewer plants were infected by the rosette disease in insecticide treated than in control plots (Fig. 14). The low incidence of rosette made the results of the trials inconclusive because the effect of each insecticide, planting date or plant spacing on the

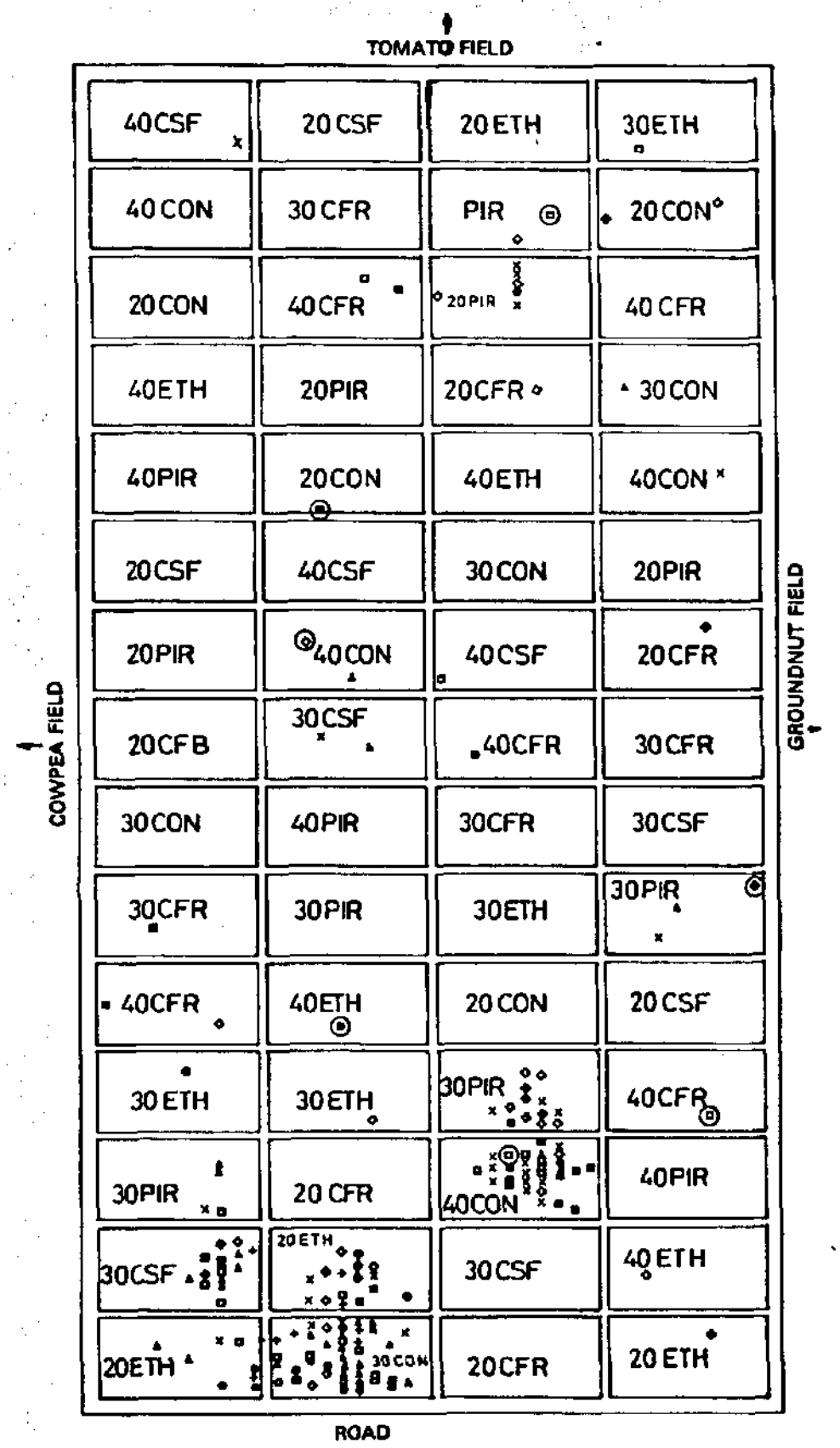


Fig. 10 The distribution and spread of green and chlorotic rosette strains on groundnut variety MK 374 (1982) Date recorded: o = 3.8; ● = 10.8; Δ = 17.8; ▲ = 20.8 □ = 27.8; ■ = 31.8, x = 6.9; ◊ = 10.9; ◆ = 17.9 (green rosette) encircled symbols indicate chlorotic rosette.

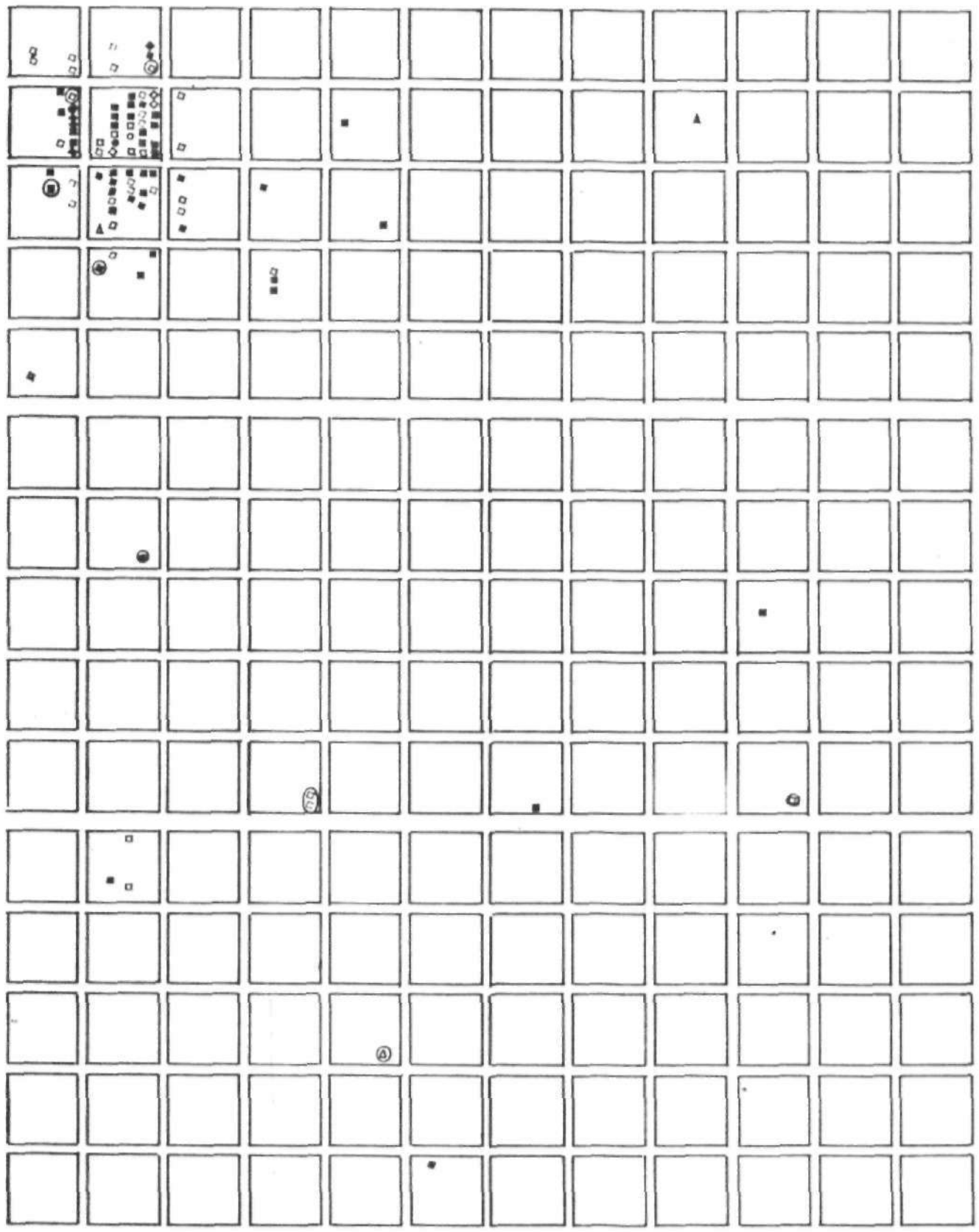


Fig. 11 The distribution and spread of green and chlorotic rosette strains in groundnut variety MK 374 (1983)
Date of recording: O = 19/7; ● = 26/7; Δ = 3/8
▲ = 10/8; □ = 13/8; ■ = 16/8; ◆ = 28/8; ◆ = 9/9
Encircled symbols represent green rosette.

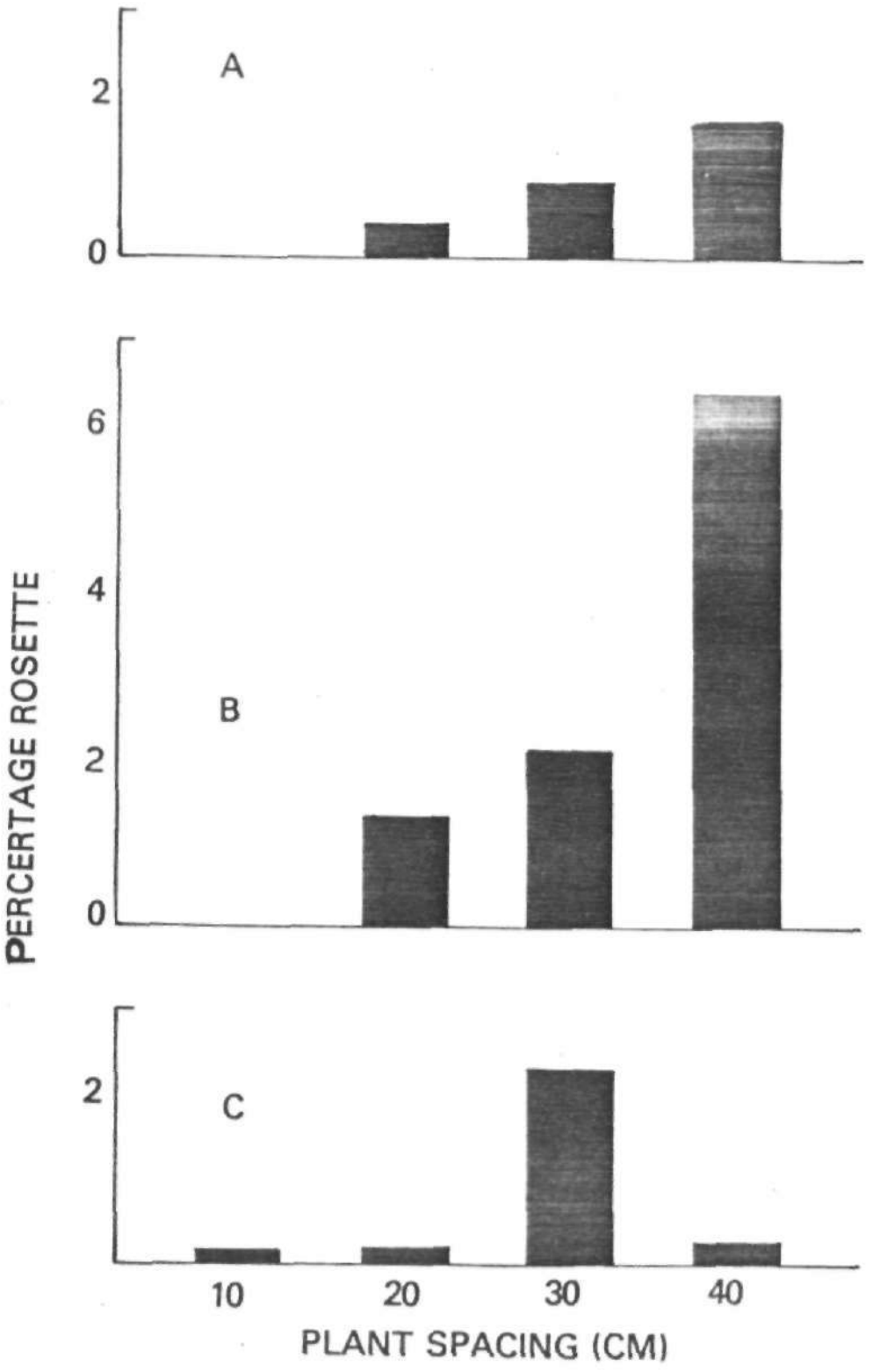


Fig. 12 The incidence of groundnut rosette disease in relation to plant spacing.

A = Variety S38 planted July 2, 1982.
B = MK 374 planted June 18, 1982.
C = MK 374, 1983 (Total of 3 planting dates).

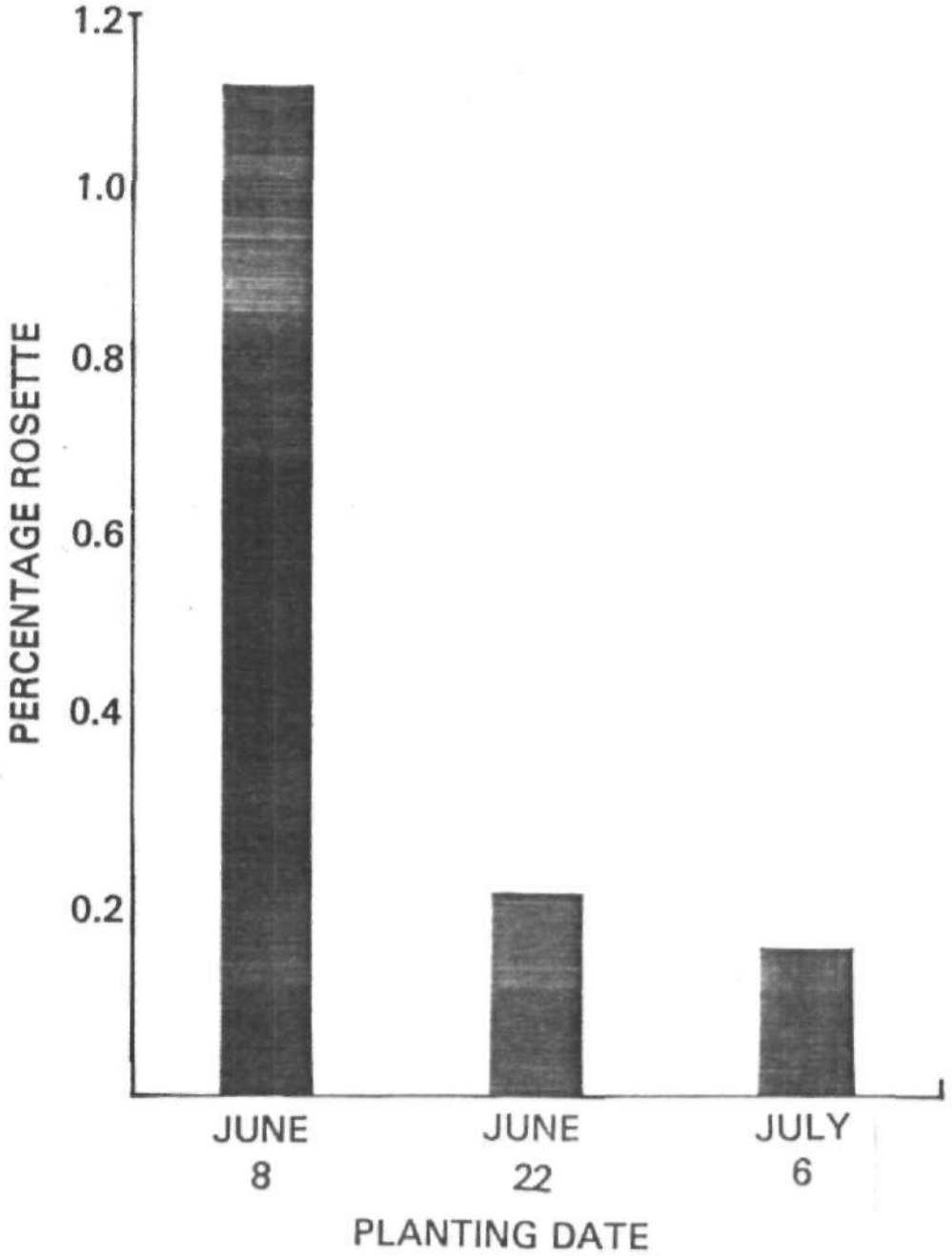


Fig. 13 The incidence of groundnut rosette disease in relation to planting dates on MK 374 (1983).

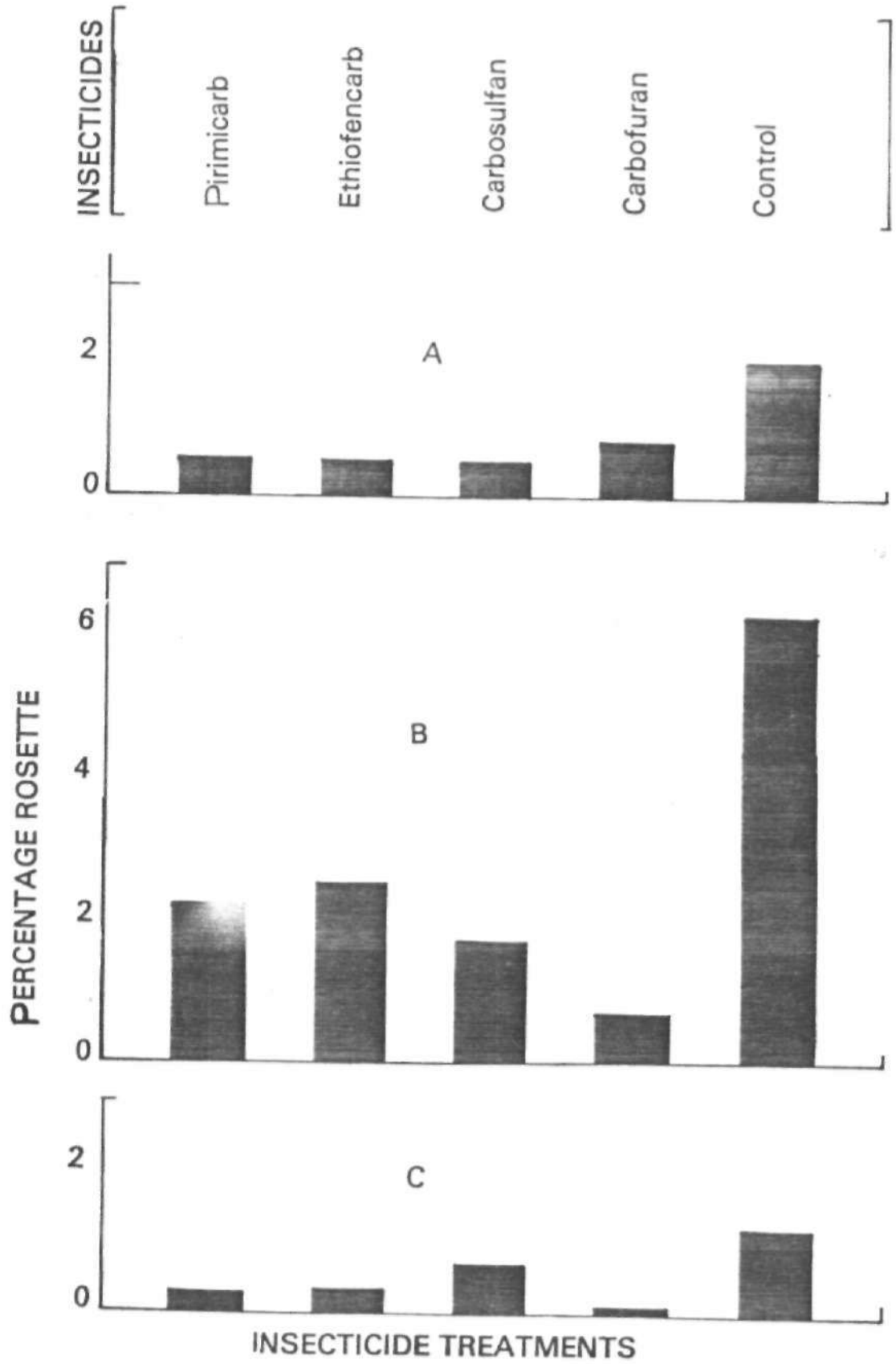


Fig. 14 The incidence of groundnut rosette disease in relation to insecticide treatments;
A = S38 planted July 2, 1982,
B = MK374 plated June, 18, 1982;
C = MK374, 1983.

incidence of rosette could not really be ascertained. However, among the insecticides, carbofuran performed better than all other insecticides tested and this could be due to better aphids control observed in carbofuran treated plots.

4.12 Spread of the virus

Because of the low incidence of rosette in both years, spread of the disease was limited to few plots only (Figs. 10 and 11). Secondary spread occurred mostly in control plots planted at 30 ro 40 cm spacings (Fig. 12). No secondary spread was observed in carbofuran or ethiofencarb treated plots, irrespective of plant spacing. None of the insecticides tested completely eliminated the aphid vector or prevented the incidence of the rosette disease (Fig. 14). However, the population of the vector and the rate of secondary spread of the rosette disease within the crop was appreciably reduced by treatment with the insecticides.

4.13 The effect of plant spacing on the yield of groundnuts

4.13.1 1982 Trials

In Trial 1 which had MK 374, the 20 cm spacing gave significantly higher pod yield and haulm yield

(P < 0.05) than the 40 cm spacing (Tables 7A and B). The differences in pod and haulm yields between the 20 and 30 cm spacings and between the 30 and 40 cm spacings were not significant. However, individual plants in the 40 cm spacing yielded considerably more pods than those in the 20 or 30 cm spacings (Table 7A). The higher pod yield obtained from individual wider spaced plants was due to sufficient space for full vegetative growth, which resulted in producing more pegs for pod setting.

In Trial 2 where S 38 was planted, the 40 cm spacing gave significantly lower pod yield (P < 0.05) than the 20 and 30 cm spacings which were statistically similar (Tables 7A and B). The haulm yield obtained from the 20 cm spacing was significantly higher (P < 0.05) than that obtained from the 30 cm spacing, while the latter gave significantly higher haulm yield than the 40 cm spacing (Tables 7A and B).

4.13.2 1983 Trials

Tables 8A and B show that the yield of groundnut decreased with a decrease in plant density. The 40 cm spacing gave significantly lower pod yield (P < 0.05) and haulm yield (P < 0.05) than the 30 cm

Table 7A. Effects of plant spacing and insecticides on the yield of groundnut (1982).

Treatment	Mean pod yield per 18 m^2 (kg)		Mean pod yield per stand (kg)		Mean haulm yield per 18 m^2 (kg)	
	MK 374	S 38	MK 374	S 38	MK 374	S 38
Plant spacing (cm)						
20	2.20	1.42	0.320	0.174	6.46	7.82
30	2.08	1.36	0.350	0.197	5.65	7.36
40	1.72	0.91	0.397	0.230	5.28	6.10
F value	5.81	12.83	5.31	3.75	5.89	39.95
LSD (P=0.05)	0.30	0.22	0.44	0.42	0.71	0.40
Insecticides						
Pirimicarb	2.07	0.91	0.366	0.167	5.75	7.01
Ethiofencarb	2.22	1.38	0.355	0.242	5.77	7.18
Carbosulfan	1.74	1.09	0.351	0.155	6.11	7.73
Carbofuran	2.26	1.94	0.370	0.305	5.17	6.78
Control	1.69	0.81	0.338	0.133	6.16	6.75
F value	3.97	20.42	n.s	14.48	n.s	4.79
LSD (P=0.05)	0.40	0.29	-	0.54	-	0.52

Table 7B. Effects of plant spacing and insecticides on pod and haulm yields of groundnuts per hectare (1982)[a/].

	Mean yield (kg/ha)			
	Pod		Haulm	
	MK 374[b/]	S 38	MK 374	S 38
Plant spacing (cm)				
20	1,223	784	3,589	4,342
30	1,153	757	3,139	4,086
40	954	504	2,933	3,386
F value	10.04	5.32	6.03	13.42
LSD (P=0.05)	174.27	149.54	456.23	251.30
Insecticides				
Pirimicarb	1,151	503	3,211	3,893
Ethiofencarb	1,235	769	3,205	3,991
Carbosulfan	968	606	3,393	4,292
Carbofuran	1,258	1,078	2,872	3,767
Control	939	452	3,423	3,750
F value	27.39	64.20	n.s	n.s
LSD (P=0.05)	221.71	275.65	-	-

a/ Based on analysis in Table 7A.

b/ The variety MK 374 was planted two weeks before S 38.

Table 8A. Effects of plant spacing, planting date and insecticides on the yield of groundnuts (1983).

	Mean pod yield per 13.5m^2(kg)	Mean kernel yield from 1kg pod sample(kg)	Mean haulm per 13.5m^2(kg)
Plant spacing (cm)			
10	3.95	0.689	6.68
20	3.90	0.662	6.56
30	3.43	0.636	6.59
40	3.18	0.625	5.86
F value	19.03	7.94	4.30
LSD (P=0.05)	0.25	0.30	0.55
Planting date			
June 8	4.63	0.701	6.00
June 22	3.79	0.675	6.41
July 6	2.42	0.582	6.87
F value	230.87	50.56	7.54
LSD (P=0.05)	0.22	0.26	0.46
Insecticides			
Pirimicarb	3.60	0.647	6.28
Ethiofencarb	3.62	0.659	6.21
Carbosulfan	3.60	0.650	6.65
Carbofuran	3.87	0.676	6.46
Control	3.38	0.633	6.51
F value	5.09	5.06	n.s
LSD (P=0.05)	0.20	0.20	-

Table 8B. Effects of plant spacing, planting date, and insecticides on the yield of groundnuts per hectare (1983)a/.

Treatment	Mean yield per ha. (kg)		
	Pod	Kernel	Haulm
Plant spacing (cm)			
10	2,923	2,013	4,948
20	2,885	1,910	4,859
30	2,544	1,618	4,882
40	2,353	1,470	4,341
F value	8.37	11.39	5.17
LSD (P=0.05)	327.11	342.75	557.00
Planting date			
June 8	3,433	2,407	4,441
June 22	2,807	1,896	4,744
July 6	1,790	1,043	5,087
F value	126.80	37.89	7.13
LSD (P=0.05)	592.43	604.52	612.86
Insecticides			
Pirimicarb	2,666	1,725	4,654
Ethiofencarb	2,684	1,768	4,601
Carbosulfan	2,664	1,732	4,924
Carbofuran	2,867	1,938	4,786
Control	2,501	1,582	4,823
F value	n.s	n.s	n.s
LSD (P=0.05)	-	223.44	-

a/ Based on analysis in Table 8A.

Table 9. Effects of plant spacing, planting date, and insecticides on the number of pods per groundnut stand (1983).

Treatment	Mean No. of pods/stand
Plant spacing (cm)	
10	39.40
20	51.30
30	60.00
40	71.20
F value	55.79
LSD (P=0.05)	5.30
Planting date	
June 8	67.60
June 22	56.10
July 6	45.60
F value	64.17
LSD (P=0.05)	4.60
Insecticides	
Pirimicarb	45.50
Ethiofencarb	57.30
Carbosulfan	53.40
Carbofuran	59.20
Control	52.80
F value	n.s
LSD (P=0.05)	-

spacing while the latter gave significantly ($P < 0.05$) lower pod yield than 10 and 20 cm spacings. The difference in haulm yield between the 10, 20 and 30 cm spacings was not significant. However, individual plants in the 40 cm spacing had significantly more pods ($P < 0.05$), than those in the 30 cm spacing while the latter had significantly more pods than those in the 20 cm spacing. Plants spaced 10 cm apart had the lowest number of pods (Table 9). The higher number of pod recorded from individual wider spaced plants was expected because each individual plant had enough space for full vegetative growth with little competition.

Kernel yields obtained from 1.0 kg pod samples showed that the 10 cm spacing gave significantly higher kernel yield ($P < 0.05$), than the 30 and 40 cm spacings which were similar. The kernel yield obtained from 20 cm spacing was significantly higher than that obtained from the 40 cm spacing. The difference between the 10 and 20 cm spacings and between the 20 and 30 cm spacings was not significant (Table 8A and B). The higher kernel yields obtained from samples in high plant densities was due to the fact that unlike in low plant densities where late pods (which were not properly filled) were harvested in fairly

large numbers together with the early set pods, only very few late pods were harvested in high plant densities and this was due to lack of adequate space for full vegetative growth which could have allowed the development of late pods.

Also, the higher yields obtained in high plant densities could be attributed to the fact that fewer aphids were recorded and the incidence of rosette disease was much lower than those recorded in low plant densities. The incidence of rosette disease has a direct negative effect on groundnut yield because rosetted plants produce fewer pods and, in severe attacks, no pods at all. The sap feeding by aphids in low plant densities was higher because of the higher aphid populations and this also contributed to the lower yield.

4.14 The effect of planting date on the yield of groundnut

Table 8A and B show that groundnuts planted on 8 June yielded significantly more pods ($P < 0.05$) than those planted on 22 June. The weight of pods obtained from the latter was significantly ($P < 0.05$) higher than that obtained from the July 6 planting. Kernel yields obtained from 1 kg pod samples showed that the

July 6 planting gave significantly lower kernel yield ($P < 0.05$) than the June 8 or June 22 planting which were statistically similar. This shows that within a given season, the shelling percentage of groundnuts decreases with increasing delay in planting. The mean number of pods obtained from individual plants in the June 8 planting was significantly more ($P < 0.05$) than that obtained from individual plants in the June 22 planting while the latter produced significantly more pods than individual plants in the July 6 planting (Table 9). This was expected because groundnut pod formation and development is heavily dependent on moisture availability and, since all the plantings were harvested on 25th October, a period completely after the rains, the later plantings were therefore not able to get enough moisture during the period of pod setting. The haulm yield obtained from groundnuts planted on 8 June was significantly lower ($P < 0.05$) than that obtained from groundnuts planted on 6 July. The difference in haulm yield between June 8 and June 22 plantings was not significant. (Tables 8A and B).

The present data obtained show that both pod and kernel yields were higher in groundnuts planted on June 8 compared to thoseplanted on June 22 or July 6.

However, the haulm yield obtained from the June 8 planting was lower than that obtained from the June 22 or July 6 plantings. The lower haulm yield from the June 8 planting could be due to higher incidence of fungal leafspots and rusts observed and also due to physiological maturity which caused higher leaf shedding.

4.15 The effect of insecticides on the yield of groundnut

4.15.1 1982 Trials

In Trial 1, where MK 374 was used, carbofuran and ethiofencarb plots gave significantly higher pod yields ($P < 0.01$) than carbosulfan and control plots (Tables 7A and B). Although the control plots produced the lowest yield, the difference between them and pirimicarb and carbosulfan treated plots was not significant. Table 7A shows that treatment with insecticides did not affect haulm yield nor did it significantly affect the pod yield of individual plants.

In Trial 2, where S 38 was used, carbofuran treated plots gave significantly higher pod yield ($P < 0.05$) than ethiofencarb treated plots. The latter on the other hand produced significantly ($P < 0.05$) higher

pod yield than pirimicarb, carbosulfan and control plots which were statistically similar (Tables 7A and B). In terms of haulm yield, carbosulfan treated plots gave significantly higher yields ($P \leq 0.05$) than pirimicarb, carbofuran and control plots which were similar (Table 7A). The difference in haulm yield between insecticides treatment in Table 7B was not significant. Unlike in Trial 1, individual plants in carbofuran treated plots in Trial 2 gave significantly higher pod yields ($P < 0.05$) than those in ethiofencarb plots. Individual plants from the latter gave significantly ($P < 0.05$) higher pod yields than those from pirimicarb, carbosulfan and control plots which were similar (Table 7A).

4.15.2 1983 Trials

Table 8A shows that the untreated control plots produced significantly lower pod yield ($P < 0.05$) than treated plots. Among the treated, carbofuran plots gave significantly higher pod yield than pirimicarb and carbofuran plots gave significantly higher pod yield than pirimicarb and carbosulfan plots which were statistically similar. There was no any significant difference in pod yields between

insecticide treatments in Table 8B. Kernel yields obtained from 1 kg pod samples in carbofuran treated plots were significantly higher ($P < 0.05$) than those obtained from pirimicarb, carbosulfan and control plots which were similar (Table 8A). Table 8B shows that the difference in kernel yield between carbofuran treated plots and control was significant ($P < 0.01$) but that between carbofuran and other insecticides was not. The difference between pirimicarb, pirimor and carbosulfan treated plots and control plots was not significant, but however, control plots produced the lowest kernel yields.

Insecticides did not significantly affect the haulm yield nor did they significantly affect the pod yield of individual plants (Table 9). They also did not affect the total haulm yield of groundnut.

All the insecticides tested gave higher pod and kernel yields compared to untreated controls. Among the insecticides, carbofuran treatment gave the highest yields. The higher yields obtained in plots treated with insecticides could be due to the lower incidence of aphids and/or rosette disease. The higher yields obtained in carborufan plots over the other treated plots was perhaps due to the fact

that other important groundnut pests such as thrips, meloid beetles, termites etc, may have been controlled in addition to the main target pest, A. craccivora.

4.16 The effects of interactions between plant spacing, planting date and insecticides on the yield of groundnut

None of the interactions significantly affected either the pod, kernel or haulm yield of groundnut (Appendices 9, 10 and 11). However, the highest pod and kernel yields were obtained in carbofuran treated plots planted on June 8 at 10 cm spacing. The effect of interaction between plant spacing and planting date on the yield of groundnut was stronger than that between plant spacing and insecticides and between planting date and insecticides.

4.17 Results and discussion on Supplementary Trials on Chemical Control

There were significantly fewer aphids in plots treated with carbofuran, Cymbush ED, pirimicarb and chlorpyrifos 10G at 30 days after planting ($P < 0.05$) as well as at 55 days after planting ($P < 0.05$) than in plots treated with carbosulfan, chlorpyrifos 25w and untreated controls. Both control and

carbosulfan treated plots, however, had significantly fewer aphids than chlorpyrifos 25w - treated plots (Table 10).

At 87 days after planting, there were significantly fewer aphids in plots treated with carbofuran ($P < 0.05$) than in plots treated with other insecticides. However, pirimicarb, cymbush ED and chlorpyrifos treated plots had significantly fewer aphids than chlorpyrifos 25w, carbosulfan and control plots (Table 10).

The present data showed that for up to 87 days after planting, there was statistically no difference in aphid control using single or double carbofuran treatments ranging from 0.75 to 2.5 kg a.i./ha. This seems to indicate that carbofuran, even when applied at the lower rate of 0.75 kg a.i./ha at planting time, can effectively prevent aphid colony formations and may protect the crop from secondary spread of rosette during the first 30 days when the crop is most vulnerable to rosette virus infection.

The expected effects of the second application of the carbofuran and chlorpyrifos 10G were not fully realised because of dry weather and tha+

Table 10. Effect of insecticides on the incidence of Aphis craccivora on groundnut variety Ex-Dakar in Samaru (1983).

Treatment	kg a.i./ha	Mean No. of aphids per 10 stands at different days after crop emergence		
		30	55	87
Chlorpyrifos 10G	3.0	16	23	2449
Chlorpyrifos 25w	600 gm/100 kg seed	314	350	3834
Carbofuran 3G	1.5	0	8	1141
Carbofuran 3G	2.5 (1.0 + 1.5)*	0	31	1592
Carbofuran 3G	1.75 (0.75 + 1.0)*	0	13	1182
Carbofuran 3G	0.75	0	20	1500
Carbofuran 3G	1.0	1	18	1640
Carbofuran 3G + Chlorpyrifos 10G	(0.75 + 1.0)*	0	10	1490
Pirimicarb 5% ED	1.0	13	20	2697
Cypemethrin/Dimethoate	1.0	10	22	1582
Carbosulfan 5% Dust	1 kg/100 kg seed	90	271	4044
Control		184	203	3266
F value		6.19	24.38	8.88
LSD (P = 0.05)		115.16	70.22	1000.00

*Indicates that two applications were done. First application at planting and second application at 40 days after first.

there were no further rains after the second application. It will therefore be worthwhile to repeat this experiment so as to determine the efficacy of particularly the carbofuran/ chlorpyrifos combination with a view to achieve an integrated foliar and soil pest management in groundnuts.

CHAPTER 5

GENERAL DISCUSSION

Immigrant alatae and small colonies of nymphs were observed in the field within 5 to 9 days after the emergence of the crop. The aphid population remained low until at 20 days after planting when immigrant alatae started arriving in fairly large numbers on the crops and in yellow water traps. There was a very rapid increase in aphid population between 20 to 40 days after planting and this could be regarded as the most important period for secondary spread of the rosette virus.

Irrespective of planting date, aphid peak populations usually occurred between the last week of July and first week of August. This indicates that peak populations always occur at a much earlier time in late than in early planted groundnuts. If the aphids are viruliferous, rosette transmission will thus be higher in late planted groundnuts which may still be growing vigorously and are still physiologically more vulnerable to infection. Even if the aphids are non-viruliferous, their sap feeding activity and the resulting injury may still

be higher in late than in early planted groundnuts because more aphids are present to feed on the crop.

Although very high aphid populations were observed in many plots, the per cent rosette incidence recorded during the experimental period was very low and uneven. This indicates that most of the aphids which attacked the crop were non-viruliferous.

Results described showed that the population of A. craccivora was inversely related to plant density. Significantly more aphids were observed in the widely-spaced than in the closely-spaced groundnuts. This showed that close spacing i.e 10 and 20 cm between stands played a very important role in the integrated control of the groundnut rosette virus and its vector, A. craccivora. The effect of plant spacing resulting in the fewer Aphis craccivora and lower incidence of rosette disease in the closely-spaced groundnuts could be due to the very good vegetative ground cover achieved by the crop witnin 20 to 25 days after planting. Very good vegetative groundcover was reported to inhibit landing of immigrant alatae in closely-spaced groundnuts (A'Brook, 1964) and this therefore

resulted in the fewer aphids attacking the crop. Because of the fewer aphids in the closely-spaced groundnuts, fewer rosette plants were also observed.

Significantly more aphids were observed in July-planted than in June-planted groundnuts. The effect of planting date resulting in the fewer A. craccivora in the June-planted groundnut could also have been due to the good vegetative groundcover achieved by the crop. Also, because the crop was physiologically mature prior to the main aphid invasion, its nutritional status may not favour the development of the aphids. The crop may also escape severe secondary rosette infection through pseudo-resistance mechanism exercised through its physiological maturity (Farrell, 1976). Therefore, in the context of the present studies, early planting could be regarded as an important component in the integrated control of the rosette virus and its vector, A. craccivora.

All the four insecticides tested significantly reduced aphid numbers compared with the untreated controls. Carbofuran gave the best control of the aphids. It gave excellent control of the vector for up to 30 to 35 days after planting even when

applied at the rate of 0.75 kg a.i./ha. Ethiofencarb was also good because it prevented the formation of aphid colonies for 8 to 10 days after each application. The four applications done at 10-day intervals kept aphid population low throughout the growing season. Carbosulfan was found to protect the groundnut crop for only 10 to 12 days after emergence. This shows that while carbofuran and ethiofencarb could protect the crop against aphids and secondary spread of the virus, carbosulfan could not do so as effectively at the tested dosage because the crop was still at a vulnerable stage when the insecticide had lost its potency. Pirimicarb could be regarded as ineffective because aphids were found in treated plots even one day after application and this could mean that if the aphids were viruliferous, the virus could easily be transmitted. None of the insecticides tested completely eliminated the aphid vector neither did any completely prevent primary rosette infection because some viruliferous aphids invariably fed and transmitted the disease before they were killed by the insecticide. However, all the insecticides tested reduced the incidence of rosette virus compared with the controls.

The effects of interactions between plant spacing, planting date and insecticides showed that better control of both the vector and the rosette virus could be achieved when insecticides such as carbofuran and ethiofencarb are applied in groundnuts planted in early June at a spacing of 10 to 20 cm. The importance of early planting and close spacing was shown in the June 8 planting where groundnut was planted at 10 and 20 cm spacings. In these plots, the difference in aphid numbers between treated and untreated plots was insignificant. This shows that if groundnut is planted in early June at a spacing of 10 to 20 cm, application of insecticides against A. craccivora may not even be necessary unless signs of heavy infestations are observed. However, when planting is delayed and plant density is low, applying insecticide is very essential for achieving a reasonable control of the vector.

Most of the predators seen feeding on A. craccivora were Coccinellidae (adults and larvae) and Syrphidae (larvae only). Those identified have been listed in the text. Because the ratio of natural enemies to aphids in both treated and control plots was very low and stood at an

average of 1:60, the natural enemies could not on their own, effectively control the aphids. A look at the data of the population dynamics of the aphids and the associated natural enemies however seems to indicate that natural enemies populations were directly dependent on the density of the aphid population. This therefore suggests that the natural enemies do play a role in aphid population regulation.

Earlier reports (Evans, 1954; Tourte and Fauche', 1956; Booker, 1963; A'Brook, 1964; Davies, 1975) showed that early planting and close spacing not only lessen the incidence of rosette but also give the highest yields in both sprayed and unsprayed plots. In the present work, groundnut planted on June 8 out-yielded that planted on June 22 and the latter out-yielded that planted on July 6. Also, groundnut planted at a spacing of 10 cm out-yielded that planted at a spacing of 20, 30 and 40 cm. The yields were found to decrease as spacing was increased from 10 to 40 cm between stands.

The highest yields were obtained in early planted and closely spaced groundnuts treated with carbofuran. The higher yields could be attributed

to the fewer aphids and rosette plants observed in those plots.

Results obtained showed that early planting had an over-riding influence on both pod and kernel yields than either plant spacing or insecticide treatment in order of importance. The role of the insecticides was not effectively realised because rosette, which is very destructive, was not prevalent during the experimental periods.

Although carbofuran and ethiofencarb performed significantly better than pirimicarb and carbosulfan in terms of aphid control, there was little difference between the four insecticides in terms of yields. However, carbofuran and ethiofencarb, which proved to be very effective against Aphis craccivora may be preferred over the other two insecticides because the former can protect the susceptible crop against an epidemic of rosette by effectively reducing the formation of colonies of the aphid vector.

CHAPTER 6

CONCLUSION

The groundnut rosette virus and its aphid vector, Aphis craccivora Koch, may effectively be controlled in Nigeria by planting groundnuts at a spacing of 10 to 20 cm early at the onsect of rains. Insecticides such as carbofuran at the rate of 0.75 to 1.0 kg a.i./ha or ethiofencarb at the rate of 0.5 kg a.i./ha can be applied in the early-planted and closely-spaced groundnuts. This would help to acheive a more reliable and reasonable degree of control of both the aphid vector and the rosette virus. Furthermore, the susceptible crop would be insured against any rosette epidemic which might occur.

Carbofuran and ethiofencarb which proved to be highly effective by reducing or even completely preventing the formation of aphid colonies during the vulnerable period of the crop are very promising in integrated control. However, it appears that carbofuran, which can be applied manually at the time of planting, may be preferred to ethiofencarb in Nigeria where most of the farmers who produce

over 90% of the total crop are illiterate. Firstly, it can be applied manually with less hazards because of its granular formulation and very high dermal LD50 of 10,200 mg/kg (ethiofencarb e.c. has a dermal LD50 of 1,000 ul/kg). Secondly, one application of carbofuran at the time of planting is sufficient to give excellent control of the aphid vector for up to 30 to 35 days post application and as little as 0.75 kg a.i./ha can be applied. Thirdly, no spraying equipment is required and there is no fear of drift.

The potential of systemic seed dressing chemicals as a prophylactic treatment should be further investigated because of the low cost involved.

Although natural enemy populations (mainly Coccinellidae and Syrphidae) were very low in the experimental fields in Samaru, their role in integrated control of the aphids should not be undermined.

For good virus/vector management in groundnuts, an integrated control approach using early planting, resistant varieties, close spacing and use of soil applied pre-plant systemic chemicals such as carbofuran should be encouraged.

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Appendix 1. Effect of interaction between plant spacing and planting date on the number of alatae, apterae and nymphs of Aphis craccivora on groundnuts (1983).

		Plant Spacing (cm)	Planting Date			
			June 8	June 22	July 6	
A)	Alatae	10	0.05[a/]	0.06	0.08	
		20	0.08	0.06	0.12	
		30	0.09	0.14	0.13	
		40	0.09	0.12	0.21	
		F value				2.92
		LSD (P=0.05)				0.07
B)	Apterae	10	0.28[b/]	0.43	0.86	
		20	0.94	0.87	1.10	
		30	1.03	1.56	1.35	
		40	1.87	1.81	2.87	
		F value				N.S
		LSD (P=0.05)				-
C)	Nymphs	10	2.80[c/]	4.70	8.60	
		20	10.30	7.60	10.90	
		30	12.30	14.50	13.00	
		40	18.70	19.80	27.50	
		F value				N.S
		LSD (P=0.05)				-

a/ = mean no. of alatae/stand.

b/ = mean no. of apterae/stand.

c/ = mean no. of nymphs/stand.

Appendix 2. Effect of interaction between plant spacing and planting date on the total number of Aphis craccivora (1983).

Plant Spacing (cm)	Planting Date			
	June 8	June 22	July 6	
10	3.60[a]	5.10	9.60	
20	11.30	8.60	12.10	
30	11.70	16.20	14.40	
40	20.60	21.70	30.60	
F value				N.S
LSD (P=0.05)				-

a = mean no. of aphids/stand.

Appendix 3. The effect of interaction between planting date and insecticides on the number of alatae, apterae and nymphs of Aphis craccivora on groundnuts (1983.)

	Planting Date	Insecticide Treatment				
		Pirimicarb	Ethiofencarb	Carbosulfan	Carbofuran	Control
A) Alatae	June 8	0.05[a]	0.04	0.08	0.07	0.13
	June 22	0.06	0.05	0.13	0.03	0.19
	July 6	0.13	0.01	0.16	0.04	0.34
	F value					2.41
	LSD (P=0.05)					0.10
B) Apterae	June 8	0.81[b]	0.14	0.83	0.31	3.05
	June 22	0.61	0.08	1.70	0.18	3.26
	July 6	0.86	0.07	2.09	0.19	4.50
	F value					N.S
	LSD (P=0.05)					-
C) Nymphs	June 8	8.6[c]	1.0	8.1	2.6	32.4
	June 22	6.9	1.1	14.8	1.2	34.4
	July 6	7.7	0.8	18.2	1.2	47.1
	F value					N.S
	LSD (P=0.05)					-

[a] = mean no. of alatae/stand

[b] = mean no. of apterae/stand.

[c] = mean no. of nymphs/stand.

Appendix 4. The effect of interaction between plant spacing and insecticides on the total number of Aphis craccivora on groundnuts (1982).

	Insecticide	Plant Spacing (cm)		
		20	30	40
A) MK374	Pirimicarb	145.5[a]	200.5	214.0
	Ethiofencarb	58.0	71.8	64.5
	Carbosulfan	178.3	197.8	233.3
	Carbofuran	19.5	24.0	17.0
	Control	241.0	327.8	318.5
	F value			2.28
	LSD (P=0.05)			41.61
B) S38	Pirimicarb	6.9[b]	5.8	7.3
	Ethiofencarb	2.3	2.8	3.1
	Carbosulfan	5.8	5.6	6.4
	Carbofuran	0.7	1.2	1.3
	Control	10.0	9.9	10.2
	F value			N.S
	LSD (P=0.05)			-

[a] and [b] = mean no. of total aphids/stand.

Appendix 5. Effect of interaction between plant spacing and insecticides on the number of alatae, apterae and nymphs of Aphis craccivora on groundnuts (1983).

	Plant Spacing (cm)	Insecticide Treatment				
		Pirimicarb	Ethiofencarb	Carbosulfan	Carbofuran	Control
A) Alatae	10	0.10	0.05	0.04	0.03	0.11
	20	0.03	0.03	0.11	0.04	0.20
	30	0.11	0.05	0.16	0.04	0.24
	40	0.08	0.00	0.17	0.06	0.28
	F value					N.S
	LSD (P=0.05)					-
B) Apterae	10	0.39	0.08	0.81	0.13	1.19
	20	0.70	0.10	1.37	0.20	2.47
	30	1.07	0.07	1.66	0.39	3.36
	40	0.89	0.13	2.33	0.19	7.38
	F value					7.59
	LSD (P=0.05)				1.18[a]/	1.14[b]/
C) Nymphs	10	4.7	0.8	7.0	1.4	12.9
	20	7.4	1.5	12.9	1.3	24.9
	30	10.4	0.5	13.8	2.5	35.7
	40	8.4	1.0	21.0	1.5	78.3
	F value					7.36
	LSD (P=0.05)				13.00[a]/	12.50[b]/

[a]/ = LSD used when comparing all the interaction means at the same time.

[b]/ = LSD used when comparing means of insecticide treat with same plant spacing.

Appendix 6. Effect of interaction between plant spacing and insecticides on the total number of Aphis craccivora (1983).

Plant Spacing (cm)	Insecticides				
	Pirimicarb	Ethiofencarb	Carbosulfan	Carbofuran	Control
10	5.20	1.60	7.80	1.60	14.20
20	8.20	1.40	14.60	1.50	27.60
30	11.50	0.60	14.50	2.90	39.30
40	9.30	1.10	23.50	1.70	85.00
F value			7.42		
LSD (P=0.05)		7 14.20[a]	13.70[b]		

[a] LSD used when comparing all the interaction means at the same time.

[b] LSD used when comparing means of insecticide treatment with same plant spacing.

Appendix 7. Effect of interaction between planting date and plant spacing on the number of natural enemies of Aphis craccivora (1983).

Plant Spacing (cm)	Planting Date		
	June 8	June 22	July 6
10	0.03[a]/	0.09	0.12
20	0.23	0.13	0.14
30	0.25	0.34	0.17
40	0.56	0.44	0.44
F value			N.S
LSD (P=0.05)			-

[a]/ = mean no. of natural enemies (Coccinellidae and Syrphidae) per stand.

Appendix 8. Effect of interaction between plant spacing and insecticides on the number of natural enemies of A. craccivora (1983).

Plant Spacing (cm)	Insecticides				
	Pirimicarb	Ethiofencarb	Carbosulfan	Carbofuran	Control
10	0.07	0.01	0.10	0.00	0.21
20	0.14	0.02	0.25	0.02	0.42
30	0.15	0.01	0.30	0.03	0.77
40	0.11	0.02	0.40	0.01	1.85
F value					13.16
LSD (P=0.05)				0.26[a]/	0.24[b]/

[a]/ = LSD used when comparing all the interaction means at the same time.

[b]/ = LSD used when comparing means of insecticide treatments with the same plant spacing.

Appendix 9. Effect of interaction between planting date and plant spacing on pod and kernel yields of groundnuts (1983).

	Plant Spacing (cm)	Planting Date		
		June 8	June 22	July 6
A) Pod Yield	10	5.26[a]	3.82	2.76
	20	4.85	4.23	2.60
	30	4.39	3.66	2.26
	40	4.04	3.45	2.04
	F value			N.S
	LSD (P=0.05)			-
B) Kernel Yield	10	0.72[b]	0.70	0.65
	20	0.71	0.69	0.58
	30	0.69	0.65	0.54
	40	0.69	0.67	0.55
	F value			N.S
	LSD (P=0.05)			-

Appendix 10. Effect of interaction between plant spacing and insecticides on the pod and kernel yields of groundnuts (1983).

	Plant Spacing (cm)	Insecticide Treatment				
		Pirimicarb	Ethiofencarb	Carbosulfan	Carbofuran	Control
A) Pod Yield	10	4.06[a]/	4.10	3.92	4.02	3.62
	20	3.74	3.89	3.88	4.00	3.96
	30	3.44	3.48	3.26	3.85	3.14
	40	3.16	3.01	3.32	3.61	2.78
	F value					N.S
	LSD (P=0.05)					-
B) Kernel Yield	10	0.67[b]/	0.71	0.69	0.70	0.68
	20	0.66	0.66	0.67	0.67	0.65
	30	0.60	0.62	0.62	0.67	0.62
	40	0.65	0.65	0.62	0.66	0.59
	F value					N.S
	LSD (P=0.05)					-

a/ Pod yield (kg)/13.5 m^2

b/ Kernel yield (kg)/1 kg pod sample.