STUDIES OF THE BIOLOGY OF THE LEGUME BUD THRIPS *MEGALUROTHRIPS SJOSTEDTI* (TRYBOM) (THYSANOPTERA:THRIPIDAE) AND ITS RESISTANCE BY COWPEA (*VIGNA UNGUICULATA* (L) WALP

BY

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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ABSTRACT

Studies on the biology of *Megalurothrips sjostedti* (Trybom) revealed that mating commenced soon after adult emergence and is characterized by lack of courtship behaviour. Mating lasted for an average time of 1 min. 44 secs ± 30 secs (range: 1 min 15 secs - 3 mins 10 secs). Oviposition began on the same day of adult emergence and eggs were laid in the leaf tissues especially in the terminal leaflets of the cowpea seedlings provided. Incubation period lasted for an average period of 2.74 ± 0.44 days (range: 2-3 days)

Nymphs on hatching were transluscent to white in colour and turned yellow after 2-3 days. The yellow form lasted for 2-3 days and changed to orange form which lasted for 3-4 days before pupating. The entire nymphal development period was 7.85 ± 0.66 days (range: 7-10 days). Pupation occurred in the soil in cells lined with silken threads. The entire pupation period took an average period of 5.48 ± 0.85 days (range: 4-7 days). Moisture was found to play an important role in pupation with pupae in dry sand dying from dessication while those in moist sand emerged normally. The entire life cycle

took 13-20 days. Parthenogenesis was observed to occur in M. sjostedti giving rise to a wholly male progeny.

Adult longevity in females took 5-22 days when food was provided and 1-2.5 days when food was not provided. On the other hand, males lived for 1-8 days when food was provided and for 1-4 days when food was not provided.

In the studies of cowpea resistance to M. sjostedti, it was observed that the local cowpea cultivars namely Nya'milambo, Katumani 4 and ICV 5 exhibited resistance in comparison to all others when the test cultivars were all planted at the same time. In a staggered planting regime which permitted subsequent synchronised flowering of all the test cultivars, Katumani 4, Ife brown and Nya'Mbita showed higher level of resistance to thrips in comparison to all other test cultivars. There was a significantly ($P < 0.05$) higher population of thrips in malformed flowers than in healthy flowers indicating that flower malformation is due to high thrips population levels.

Data collected for yield loss due to thrips showed that there were no significant ($P = 0.05$) differences among the test cultivars regardless of whether or not the plants were sprayed against thrips. It was therefore concluded from these observations that thrips population levels of 2-7 thrips per flower did not affect cowpea yields in Western Kenya.

CHAPTER 1

1. Introduction

1.1 The cowpea crop and its importance and uses

The cowpea *Vigna unguiculata* (L) Walp also known as southern pea, blackeye pea, lubia, niebe, coupe or frijole is an annual leguminous plant (Blackhurst, 1980). Some cultivars may be spreading, others may be semi-upright or erect in growth habit. Their flowers may be purple, pink, white, blue or yellow in colour. The pods of most varieties hang downwards, while others may point horizontally or vertically. The seeds are varied in colour. The plant is self pollinating with about 2% cross pollination (Acland, 1971).

There has been controversy on the centre of origin of the plant as evidenced by information available in literature (Kornicke, 1885 in Piper 1913; Wight, 1907; Watt, 1908; Piper, 1913; Vavilov, 1935; Ames, 1939; Chevalier, 1944; Burkill, 1953; Sellschop, 1962; Zhukovskii,1962; Rawal, 1975; Steele, 1976; Chandel *et al*., 1978). There is however, substantial evidence which indicate that the most likely centre of origin of this species in Africa is Nigeria (Rachie and Roberts, 1974; Faris, 1965; Mwanze, 1971).

Cowpea attains its importance as a high protein food crop for millions of people with poor nutritional standards (Singh, 1980). This is particularly true of the tropics where the problem of protein deficiency and

malnutrition are chronic and cowpea and other pulses provide relatively cheap and locally available sources of energy, minerals, vitamins and roughage for both man and livestock (Khaemba, 1980). In addition, the crop has miscellaneous uses in the maintenance of soil fertility by their ability to supplement soil nitrogen through atmospheric nitrogen fixation, green manure and prevention of soil erosion (Okigbo, 1978; Singh, 1980). It also thrives well in marginal soils, smothers weeds and takes a short period to mature.

In Kenya, cowpea offers the best alternative as the cheapest source of grain legume on the market. Apart from common beans, it is the least expensive, most easily transported, non processed proteinaceous food concentrate for both rural and urban utilization (Khaemba, 1980). In semi-arid areas of Eastern Kenya, early maturing determinate types are grown mainly for grain production. In areas with moderate rains (e.g. Coast province), medium maturing types yielding both grains as well as leaves are grown. In Western and Nyanza provinces of Kenya (high rainfall areas), late maturing indeterminate types are grown mainly for leaves rather than for grains (Muruli et al, 1980).

1.2 Cowpea distribution, production and yield constraints .

Cowpea is predominantly a hot weather crop well adapted to semi-arid and tropical forest margins.. Its ability to grow

vigorously under a wide range of environments and poor soils is particularly advantageous in subsistence farming (Khaemba, 1980). The major regions of cowpea production extend from the United States to Eastern Australia, an area about 25° north and 25° south of the equator (Singh, 1979). It is grown widely throughout the tropical lowlands of Africa where it forms a major component of the cropping systems (Rachie and Roberts, 1974; Ligon, 1958). The main cowpea production countries in Africa are Niger, Mali, Chad, Nigeria, Burkina Fasso, Sierra Leone and Senegal in West Africa, Uganda, Kenya, Tanzania and Sudan in Eastern African and South Africa and Zimbabwe in southern Africa (Sellschop, 1962; Rachie and Roberts, 1974; Singh, 1979).

In Kenya cowpea is the second most important pulse to the common bean (Phaseolus vulgaris L.) and occupies about 271,200 hectares of crop land and is mostly grown in mixtures with other crop such as pigeon pea, maize and sorghum (Muruli et al, 1980). About 85% of the crop is produced in the marginal rainfall areas of the Eastern province while 8% is grown in the Coast province and the remaining proportion of 7% in the Nyanza, Western and Central provinces (khaemba, 1980).

Accurate estimates of cowpea yields measured as dry grains are difficult to obtain and vary a great deal in different parts of Kenya. Cowpea grain yields as low as 80 kg/ha have been recorded in Kenya (Khamala, 1978). On the other hand, high yields of up to 1242 kg/ha have been recorded

in experimental plots in Kenya (Muruli et al, 1980). The low figure recorded by Khamala (1978) was explained by Khaemba (1980) that obtaining high yields has largely been hindered by the low yielding capacity of some of the local cultivars which tend to grow vegetatively, poor agronomic practices and ecological constraints such as temperature and rainfall and especially phytophagous insects.

In the cowpea growing areas of Africa, cowpea production suffers most from insect pests. The legume bud thrips Megalurothrips sjostedti (Trybom) alone has been recorded to cause yield losses from 50% (Whitney, 1972) up to 100% (Wien, 1979). As a result, of this, cowpea has been considered by farmers as a high risk crop under monoculture (Singh, 1979). This is well demonstrated by the spectacular increase in yields, sometimes up to ten fold often obtained following insecticide application (Booker, 1965b; Kayumbo, 1975; Koehler and Mehta, 1972; Taylor, 1968). Despite this, most African farmers have not been able to adopt spraying their cowpea fields with insecticides. This calls for the cultivation of cultivars naturally resistant to insect attack.

Research on cowpea resistance to insects started about a decade ago especially at the International Institute for Tropical Agriculture (IITA) based in Ibadan,Nigeria. In Kenya, research on cowpea resistance to insects is of recent origin and is still very limited. Apart from studies by Nganga

(1980), studies of cowpea resistance to M. sjostedti in Kenya is almost non-existent. In addition, resistance of local cowpea cultivars to various pests has not been quantified. The present study was carried out to evaluate host plant - pest relationship between selected cowpea cultivars and the legume bud thrips M. sjostedti.

CHAPTER 2

2. LITERATURE REVIEW

2.1 General cowpea entomology

Evidence accumulated from cowpea growing regions of the world strongly indicate that the cowpea crop is vulnerable to insect pest infestation from seedling to harvesting and thereafter (Wilson and Genung, 1957; Le Pelley, 1959; Appert, 1964; Taylor, 1964; Booker, 1965b; Forsyth, 1966; Halteren, 1971; Kayumbo, 1975; Singh, 1977a; Khamala, 1978; Singh et al, 1978; Singh and Taylor, 1978; Nyiira, 1978). Moreover, a large number of cultivated legumes and many species of leguminous plants are alternative hosts of the same pests that attack cowpea (Taylor, 1971; Singh et al, 1978).

Cowpea pests have been classified in different ways by different authors. Phelps and Oosthuizen (1958), Smartt (1976), Singh (1977a, 1978) and Khamala (1978) classified the pests according to their taxonomic order. Singh and Taylor (1978) classified cowpea pests according to their order of colonization of the cowpea crop. Singh and Van Emden (1979) used two of the characteristics mentioned above (i.e.taxonomic order and order of colonization of crop) to classify cowpea

pests. Booker (1965b) and Singh (1974) divided cowpea pests into two major groups; pre-flowering and post-flowering pests. Taylor (1971) further sub-divided these groups into four major categories, namely, root-feeding species, leaf feeding species, flower-feeding species and pod and seed-infesting species. This classification was later adopted by others (Singh, 1975; Khamala 1978; Nyiira 1978; Ochieng 1978; Khaemba, 1980). The method of classification used in this review is a combination of all the systems mentioned above for it provides information on the different colonization periods by various insect taxa in relation to the cowpea crop phenology and at the same time separates out different species of the same taxa colonizing at different plant growth stages.

The earlier literature on cowpea entomology in Kenya (Le Pelley, 1959; de Pury, 1968) provided fragmented and scanty information. However, lately, various authors have documented considerable information on cowpea entomology (Nganga, 1977, 1980; Khamala, 1978; Khaemba, 1980; Muruli et al, 1980; Karel and Malinga, 1980; Khaemba and Khamala, 1978; Ocheing et al, 1981; Okeyo-Owuor and Ochieng, 1981; Dabrowski et al, 1983; Macfoy et al, 1983; Mabonga, 1983; Suh and Simbi, 1983; Macharia,1984).

2.2 Pre-flowering insect pests

The pre-flowering insect pests of cowpea can taxonomically be classified into four groups, namely;

lepidopterous root and leaf feeding species, coleopteran root and leaf feeding species, homopteran species and thysanopteran leaf feeding species.

Khamala (1978) reported that the larvae of the cutworm Agrotis ypsilon (Schiff) was commonly associated with cowpea roots in Kenya. A. ypsilon together with other species which include Diachrysia orichalcea (F), Agrotis segetum (Dennis & Schiff) and Spodoptera spp. have also been recorded feeding on stems and leaves of cowpea in Kenya (Le Pelley, 1959; Hill, 1975; Khamala, 1978). Spodoptera spp. and Amsacta moleneli Hmphs have been recorded in Senegal (Delassus, 1970). Booker (1965a) recorded Amsacta flavizonata Hmphs as a minor pest of cowpea in northern Nigeria. Taylor (1968) observed several undetermined species of pyralidae larvae damaging growing tips of cowpea in southern Nigeria. He also recorded Diacrisia maculosa Cram, D. lutescens and Euproctis spp. on cowpea shoots. Nyiira (1978) recorded Acrecercops spp. Dasychira mendosa (Hb), Maenas arborifera, Hedylepta indicata (Fabricius), Chrysodeixis acuta (Wlk) and Diacrisia orichalcea (Fabricus) as minor foliage pests of cowpea in Uganda.

Among the foliage-feeding beetles of cowpea, Ootheca mutabilis Sahlb is considered the most important in East and West Africa (Le Pelley, 1959; Booker, 1963, 1965a&b; Halteren 1971; Singh, 1977a, 1978, 1979; Singh and Taylor, 1978; Singh and Van Emden, 1979). The importance of O. mutabilis lies in

its sporadic and unpredictable outbreaks on the crops, the extensive damage it causes to cowpea seedlings leading to plant death at high beetle population (Taylor, 1971) and its ability to transmit the cowpea yellow mosaic virus even at low populations (Chant, 1959, 1960; Whitney and Gilmer, 1974; Robertson, 1963; Shoyinka, 1974). Taylor (1971) also indicated that the larvae of this pest probably fed on roots of cowpea seedlings. The foregoing observation was confirmed by Ochieng (1978) in his biological studies of the pest.

In Kenya, O. mutabilis has been reported to feed on young cowpea leaves and may defoliate the crop (Khamala, 1978) and is a known vector of cowpea mosaic virus (Bock, 1971). A related species Ootheca bennigseni Weise has been reported on cowpea in Kenya (Nganga, 1977) and is known to cause defoliation of cowpea seedlings in Tanzania (Bohlen, 1973; Enyi, 1974; Kayumbo, 1975, 1978). The following beetle species; Nematocerus spp., Phoromitis largus Marshal,' Barombia humeralis Lab, Leperodes lineata Kars, Chrysolagria cuprina Thoms, Lagria villosa F., Epilachna spp. and Alcidodes leucogrammus Erichsow.have been reported to be of less importance to cowpea growing in Kenya (Khamala,1978). The larvae of the beetle Anomala spp. and Apogonia african Cast are known to attack cowpea roots in Nigeria (Taylor 1971) while the foliage beetle Medythia quaterna (Fairm) has been reported to

feed on young leaves of cowpea seedlings and is an important vector of cowpea mosaic virus in West Africa (Whitney and Gilmer, 1974).

Leafhoppers of the genus Empoasca are widely distributed in tropical Africa (Singh, 1979). Studies by Parh (1976) revealed that Empoasca christiani was the predominant species followed by E. dolichi (Paoli) with a small population of E. knudseni and E. pikna Dworakowska in southern Nigeria. Singh (1975) reported E. dolichi as an important pest of cowpea during the seedling stage in West Africa. E. dolichi has also been reported as a minor pest of cowpea in Kenya and Uganda (Le Pelley, 1959).

Reports exist which show that cultivation of certain cultivars susceptible to leafhoppers often result in yield losses due to damage caused by Empoasca spp. in Africa (Karel, 1977; Raman et al, 1978; Parh, 1979). Reports by Malinga (1978) and Karel and Malinga (1980) in Kenya revealed that TVu 59, TVu 123 and TVu 1190 cultivars were resistant to Empoasca spp. Their work however, was mainly on the West African cultivars and not the local cowpea cultivars.

The cowpea or groundnut aphid Aphis craccivora Koch which is the main aphid pest of cowpea was originally considered a minor pest in Africa. In his report, Singh (1979) indicated that heavy aphid population are becoming more frequent and widespread in Africa. The pest infests cowpea

crops in Nigeria (Booker,1965a; Singh,1977a) Egypt (El-Sebae and Saleh,1970; Hammad,1978), Tanzania (Le Pelley, 1959; Kayumbo,1975) and also in Kenya (Malinga,1978; Anon,1982; Reddy,1984). A.craccivora attack the crop at the seedling stage and heavy infestations may result in stunted plants with distorted leaves and small, poorly nodulated rooting systems.

Singh (1979) reported that an indirect and even more serious damage by this pest even when populations are small, is the transmission of cowpea aphid-borne mosaic virus. Several cowpea cultivars resistant to A. craccivora such as TVu 410, TVu 810, TVu 408-P-2 and Vita 1 have been developed (Singh,1979). Khamala (1978) reported the cotton aphid Aphis gossypii Glov and the black bean aphid Aphis fabae Scop as attacking various legumes including cowpeas in Kenya. A. fabae has also been reported as a pest of localised but considerable economic importance to cowpea in Uganda (Nyiira, 1978)

Nyiira (1978) also reported that Thrips tabaci Lind was a serious pest of cowpea during dry spells in Uganda. He further reported that Frankliniella schultzei (Trybom) also attacked cowpea with heavy populations of this thrips occurring around the fourth week of cowpea crop development. The legume foliage thrips Sericothrips occipitalis Hood has been reported as a minor foliage pest of cowpea seedlings in Nigeria (Singh and Taylor, 1978; Singh and van Emden, 1979) and only becomes serious under glasshouse conditions (Taylor, 1969) or under

severe drought on seedlings of off-season crops grown under irrigation (Singh, 1977a; Singh and Taylor, 1978). However, infestation usually declines with the onset of rains and the plants appear to recover fully (Singh, 1977a).

2.3 Post-flowering insect pests

Post flowering insect pests of cowpea can taxonomically be classified into four groups, namely, Coleopteran flower feeding species, Lepidopterous flower, pod and seed-infesting species, Hemipteran pod sucking bugs and Thysanopteran flower feeding species. Since the emphasis was on field pests, storage pests of cowpea are not covered in this review.

The blister beetles Coryna spp. and Mylabris spp. have been recorded in Kenya and attacks have been said to be serious on their outbreaks (Khamala 1978). Nyiira (1978) recorded Coryna apicornis (Guerin) and Mylabris amplectens Gerstaecker in Uganda, while M. farguharsoni Blair was recorded in Nigeria (Singh and Taylor, 1978). The adult beetles feed on flowers and flower buds and their damage is often sporadic and serious (Singh, 1979).

A number of lepidopterous pests infest cowpea at both the flowering and post flowering stage. These include the

legume pod borer Maruca testulalis (Geyer), the African bollworm Heliothis armigera Hubner and the cowpea seed moth Cydia ptychora Meyrick. M. testulalis is a major pest of grain legumes (including cowpeas) throughout the tropics (Booker, 1963, 1965b; Taylor, 1963, 1967, 1978; Taylor and Ezedinma, 1964; Jerath,1968; Koehler and Mehta, 1972; Bohlen,1973; Raheja,1974; Summerfield et al, 1974; Khamala,1978; Singh and van Emden,1979). The larvae of M. testulalis feed on the floral parts and the green pods of cowpea though it establishes itself on the crop during the pre-flowering stages when it infests the peduncles and the tender parts of the stem (Singh and van Emden, 1979). Cowpea yield losses due to this pest have been estimated to range between 20% and 60% in West Africa (Taylor,1964,1967,1968; Taylor and Ezedinma, 1964; Jerath, 1968; Ayoade, 1969; Morgan, 1973; Singh and Taylor, 1978). Yield losses of between 10% and 80% have been recorded in Western Kenya (Okeyo-Owuor and Ochieng, 1981)

H. armigera is an important pest of flower buds, flowers and green pods of cowpea (Singh,1979) especially when cowpea is intercropped with maize (Singh and van Emden,1979). This pest was originally considered to be the most important pest of grain legumes in Kenya (Khamala,1978). However, recent studies conducted on small plots in Kenya have indicated that M. testulalis was the predominant species present in cowpea in the hot and humid areas of the Coast and Nyanza provinces and

in the semi-arid regions of Eastern and North-eastern provinces of Kenya (Khaemba, 1980).

C. ptychora is a pest of ripe and dry unharvested pods in which it bores and feeds on the seeds in East and West Africa (Le Pelley, 1959; Taylor, 1965; Halteren, 1971; Nyiira, 1971, 1978; Roberts and Chipeta, 1972; Singh, 1977a; Singh and Taylor, 1978). It lays its eggs commonly on the peduncles of pods. On hatching, the first instar larvae enter the pods that are near maturity and feed on the seeds, remaining inside the pod until they are about to pupate (Singh and Taylor, 1978).

The most common pod-sucking bugs are in the genera Anoplocnemis, Clavigralla, Mirperus (Coreidae), Riptortus (Alylididae) and Nezara (Pentatomidae). Foremost among the bugs are the two nearly cosmopolitan bugs Riptortus dentipes (Fabricius) and Anoplocnemis curvipes (Fabricius) identified to be of economic importance wherever cowpea is grown in Africa (Le Pelley, 1959; Phelps and Oosthuizen, 1958; Booker, 1965b; Taylor, 1968; Bohlen, 1973; Agyen-Sampong, 1978; Kayumbo, 1978; Khaemba and Khamala, 1981). They attack cowpea during the podding stage, the time when its compensatory mechanisms have ceased functioning (Wien and Tayo,1978). Other four species, Clavigralla shadebi stal, Clavigralla tomentosicollis Stal. Nezara viridula (L) and Mirperus jaculus (Thnb) are important pests of cowpea in Nigeria (Booker, 1965a & b; Singh and Taylor, 1978), while the first three of the four species have

been recorded in Kenya (Nganga, 1977; Khamala, 1978; Macharia, 1984; Reddy, 1984).

2.3.1 Thysanopteran flower feeding species

The legume bud thrips Megalurothrips sjostedti (Trybom) a synonym of Taeniothrips sjostedti, is a major pest of cowpea in Africa. The original species name T. sjostedti was used earlier by various authors. These authors included Okwakpam (1965, 1967), Taylor (1969, 1974), Koehler and Mehta (1972), Whitney and Sadik (1972), Singh (1973, 1977a); Whitney et al (1974) and Ochieng (1977) among others. The synonym M. sjostedti has been applied by various authors which include Nyiira (1978), Okwakpam (1978), Singh (1978, 1979), Singh and Taylor (1978), Taylor (1978), Singh and van Emden (1979), Wien (1979), Ghauri (1980), Roesingh (1980), Ezueh (1981), Dina (1982) and Salifu (1982, 1984), among others. The genus synonym Megalurothrips had earlier been known and used by Bhatti (1969).

According to Karny (1914), Faure (1960), Jacot-Guillarmod (1974), Hill (1975) and Strassen (1981, 1982), M. sjostedti is only found in Africa: Gambia, Ivory Coast, Nigeria, Cameroon, Guinea, Ghana, Gabon, Congo, Niger, Togo,

East Africa, South Africa, South-west Africa, Mozambique, Zimbabwe, Mauritius, Cape Verde Islands, Comoro islands and Malta.

M. sjostedti is mainly a pest of flower buds and flowers. Flower buds that escape damage may be infested later when they become flowers. These flowers are often distorted, malformed and discoloured and fall off when infestation is severe (Taylor,1978). M. sjostedti has also been reported to transmit the yellow strain of cowpea mosaic virus (Anon, 1978).

Whitney (1972) and Wien (1979) reported seed yield reduction of up to 50% and 100% respectively on cowpea due to damage by M. sjostedti in W. Africa. Whitney (1972) further reported that plant height, flower initiation, number of pods set, pod length, number of pods harvested, percentage of pods with seeds, number of seeds per pod, weight of seeds per plant, per pod and per 100 seeds and date of maturity were all affected by thrips. However, Ezueh (1981) reported that significant depression of dried grain yield of cowpea by M. sjostedti only occurred if infestation extended beyond 35 days after planting.

Ingram (1969) suggested that no real damage was done by thrips in Uganda since killing them did not result in yield increases in beans. Nyiira (1978) also reported that attempts to assess the effect of thrips on bean yields was carried in Uganda but no clear cut conclusion was reached although it was

observed that there was some association between thrips population and the number of seeds per pod and pod size.

There is some evidence to show that insecticides could substantially control thrips population and thus raise cowpea yields. Singh and Taylor (1978) reported that monocrotophos, chlorpyrifos ethyl and cyanolate were the most effective chemicals against thrips at 500 g.a.i./ha, followed by BHC, DDT, and methomyl at 800 g.a.i./ha. Just one application at flower bud formation was found to be sufficient for control of flower thrips. Singh et al (1981) also reported that with each increase in monoctotophos insecticide dosage applied, there was an increase in yield and a reduction in the number of thrips. Earlier, Ayoade (1975) reported that Monocrotophos afforded better control for M. sjostedti and thereby induced higher yields than when DDT and a mixture of carbaryl and molasses were applied on the early crop.

However, farmers in Africa have not been able to adopt the use of chemical insecticides with the result that farm yields of cowpea have remained low. Singh (1978) attributed this to the farmers disinterest and reluctance in the use of the costly insecticides for cowpea which is a comparatively low value crop. He also attributed this to acute scarcity of insecticides and sprayers and to the inadequate number of spray applications due to difficulties of transporting water. Noting that cowpea production was still limited by insect

pests, Jackai and Singh (1983) attributed this to non adoption of technology pertaining to chemical control mainly because of lack of know-how by the farmers due to inefficient extension services to guide them on which chemicals to apply and how and when to apply them and due to the financial constraints. They further noted that should these constraints be overcome, then there is real danger of over-use of chemicals. This will increase the risk of environmental pollution, the incidence of pest resistance and human poisoning.

This situation makes it imperative that other control options be investigated which although not a necessary replacement for insecticides, but rather as a part of an integrated strategy for combating cowpea pests. Singh (1978) and Jackai and Singh (1983) were of the view that one realistic approach to solving the problems posed by insecticides was the development of insect resistant cowpea cultivars.

2.4 Host Plant Resistance

Snelling (1941) defined plant resistance as "including those characteristics which enable a plant to avoid, tolerate or recover from the attacks of insects under conditions that would cause great injury to other plants of the same species. Painter (1951, 1958) gave a slightly different definition. He defined host plant resistance as the relative amount of

heritable qualities possessed by a plant which influence the ultimate degree of damage done by the insect. In practical agriculture, it represents the ability of a certain variety to produce a large crop of good quality than do ordinary varieties at the same level of insect population.

Painter (1951, 1958) went on to categorize insect resistance as observed in the field into three types: non-preference (which renders the plant unfit or unattractive to insect pests as food, for oviposition or for shelter), antibiosis (in which a plant is resistant by exerting an adverse influence on the growth and survival or reproduction of the pest) and, tolerance (that imparting the ability to withstand or to recover from injury despite supporting a pest population that would severely damage susceptible hosts). Pathak (1972) and Singh (1978) were of the opinion that the word relative was important in Painter's definition since host plant varieties immune to insect attack have seldom been recorded and even highly resistant varieties suffer a certain amount of damage provided the insect infestation is high enough.

Beck (1965) in his review defined plant resistance as being the collective heritable characteristics by which a plant species, race, clone or individual may reduce the probability for successful utilization of that plant as a host by an insect species, race, biotype or individual. Beck thus dropped tolerance from the traditional concept of host plant

resistance. However, the three authors all agree that resistance is genetically determined.

Resistance though genetically controlled is greatly modified in expression by the environment through various effects on the insect and on plant physiology (Van Emden, 1966; Johnson, 1968; Singh, 1970). For example increased or reduced temperature may lead to loss or reduction of resistance (Dahms and Painter, 1940; Platt, 1941; Cartwright et al, 1946; Holmes et al, 1960; Roberts and Tyrell, 1961; McMurty, 1962; Isaack et al, 1965; Wood and Starks, 1972; Lowe, 1974). Additionally Rogers and Mills (1974) showed that there was reduced resistance in some resistant sorghum varieties to the maize weevil Sitophilus zeamais Motschulsky with an increasing relative humidity. Other factors which might affect the expression of resistance are, insect factors (insect abundance, activity, disease transmission and mutation and biotypes) and plant factors (protective features, hybrid vigour, mechanical structure, chemical composition, sensitivity to insect feeding and secretions, disease susceptibility and maturity (Painter, 1951).

Plant resistance as a method of insect control offers many advantages. In some cases it may be the only method available that is effective, practical and economical (Horber, 1972; Pathak and Saxena, 1976). Resistance developed in plants for one pest species may provide resistance to others (Way and

Murdie, 1965; Gahukar and Chiang, 1976). For farmers in developing countries, perhaps the most attractive feature of growing pest resistant varieties is that virtually no skill or cash outlay is required on the part of the farmers (Maxwell and Jennings, 1980).

There are however some problems in relying exclusively on plant resistance for pest control. High levels of resistance due to monogenic control may lead to the development of new insect biotypes as has happened with the brown planthopper in rice in the Philippines and the Chesnut gall wasp, Dryocosmus kuriphilus Yasumatsu in Japan (Shimura 1972). In addition, resistance may not be expressed in every environment in which the variety is grown (Horber, 1972; Kogan, 1975; Coppel and Mertin, 1977).

Painter (1951) stressed that resistant varieties are not a panacea for all pest problems. To be most effective, they must be carefully fitted into control systems designed for specific pests and into the plant improvement programmes of particular crops. He categorized the use of resistant varieties in pest management as follows: the principal control method, on adjunct to other measures; and, a safeguard against the release of more susceptible varieties that exist at the present time. He further noted that resistant varieties usually have to be integrated with other methods of pest control to achieve stable pest suppression. Pimentel (1969),

Maxwell (1972), Horber (1972) and Dahms (1972) added further that resistant varieties, even those with low and moderate levels of resistance, offer a number of advantages to an integrated control system. The reduction in pest numbers achieved through resistance is constant and practically without cost to the farmers. Such a reduction also makes control by chemical and cultural methods easier and the level of natural biological control required to hold pest numbers below crop damaging levels need not be so great.

It is apparent from the available literature that the biology of M. sjostedti in East Africa is little understood. The work done on this species has been generally confined to the humid tropics of West Africa and virtually nothing is known about this species in Kenya.

Additionally, since host plant resistance may form a major component in a pest management strategy against this insect, it is essential that the interaction of M. sjostedti with different cowpea cultivars be screened to identify some of the resistant cultivars within the Kenyan germplasm.

In view of this, it was decided to carry out a detailed study on the biology of M. sjostedti and its interaction with different local cowpea cultivars.

2.5 OBJECTIVES

1. To study and describe various aspects of the basic biology of M. sjostedti.

2. To assess the resistance/susceptibility responses of 8 selected local cowpea cultivars to M. sjostedti infestation through:

   . thrips population assessment
   . yield loss assessment.

CHAPTER 3

STUDIES ON SOME ASPECTS OF THE BIOLOGY OF LEGUME BUD THRIPS *M. SJOSTEDTI* WHEN REARED ON COWPEA

3.1 Introduction.

M. sjostedti is a major pest of cowpea throughout tropical Africa. Previously, very little was known of its biology. However, Okwakpam(1978) made extensive studies on various aspects of the biology of *M.sjostedti*. Okwakpam (1978) recorded an entire life cycle of 16-20 days while Singh and Allen (1979) reported a life cycle of 14-18 days.

In West Africa, the eggs are laid on leaves, flower buds and flowers (Okwakpam,1978; Singh and Taylor,1978; Singh and Allen,1979; Singh and van Emden,1979). Okwakpam (1978) recorded an incubation period of 3.04 days for *M sjostedti*. He also recognized three larval stages for thrips all of which fed within the flower. Pupation occurs in the soil (Hill, 1975) and has been reported to take 5-6 days in W.Africa (Okwakpam, 1978). The adult thrips are shiny black and feed on flower buds and flowers (Singh and Taylor,1978; Singh and van Emden,1979).

Despite these studies, certain aspects of the biology of *M. sjostedti* such as mating behaviour and adult longevity among others still remain unknown. Furthermore, no attempts

have been made to study its biology in Kenya. Ortman and Peters (1980) stressed that before embarking on a plant resistance programme or any pest management programme there must be a significant pool of information on the pest biology.

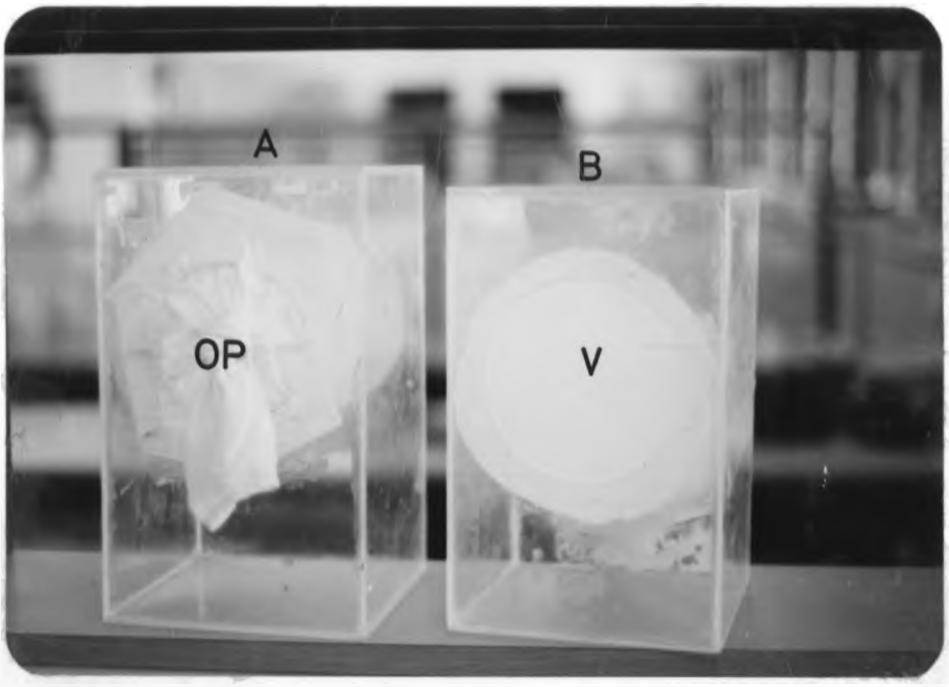
This study was carried out to investigate various aspects of the biology and behaviour of M. sjostedti. These included the mating behaviour, incubation period, nymphal period, role of moisture in pupation, pupation period, adult longevity, and sex ratio.

3.2 Materials and Methods

3.2.1 General procedure

Rearing of adult and nymphal stages of thrips was carried out inside perspex cages measuring 28 x 18 x 18 cm (height x width x breadth) with two open sides covered with white nylon clothing material for ventillation (Plate 1). They were fed on cowpea seedlings of approximately ten days old which had been planted as seeds and raised in cylindrical plastic containers measuring 5 x 5 cm (height x diameter) (Plate 2). To ensure adequate supply of seedlings, cowpea seeds were planted at intervals of five days and were tended in an insect free room to avoid infestation by thrips and other insect pests.

Plate 1. Perspex cages used for rearing M. sjostedti



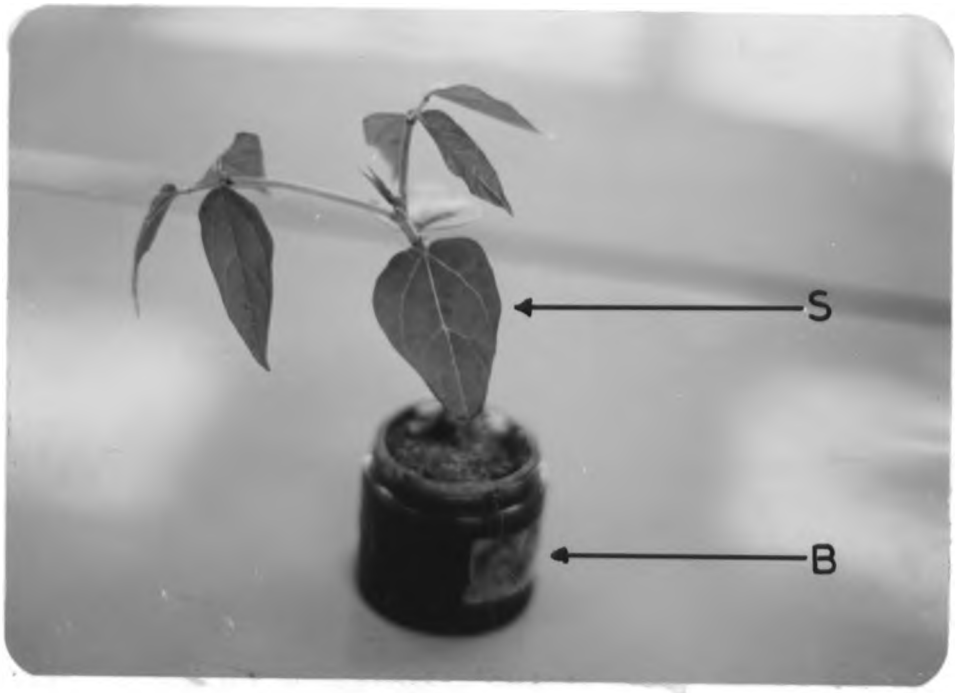
A - Front view

B - Back view

V - Ventillation

OP - Opening

Plate 2. Ten day old cowpea seedlings on which M.sjostedti were reared



B - Bottle

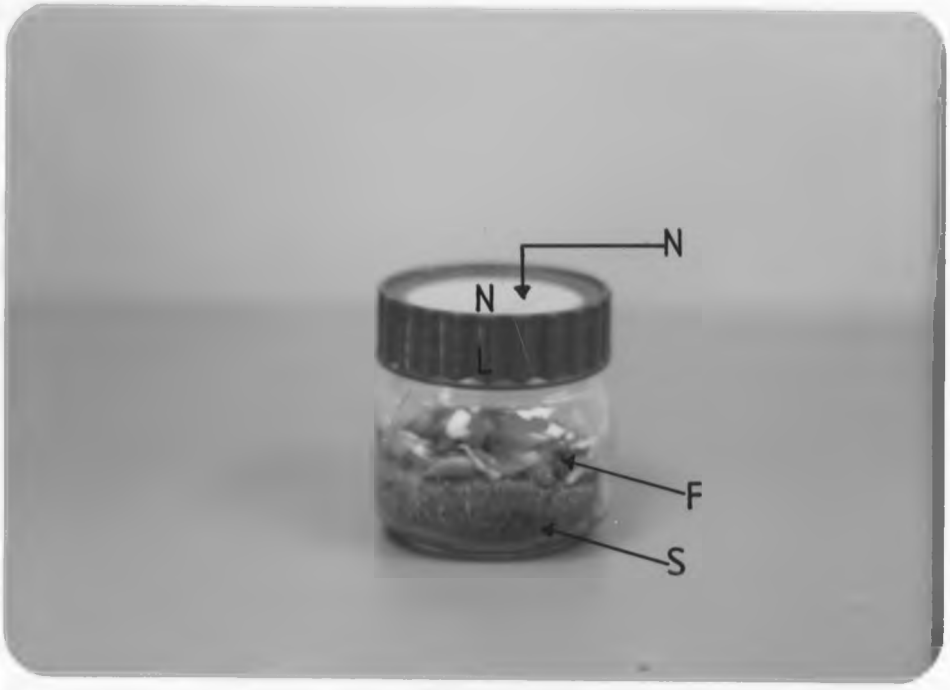
S - Seedling

For experiments involving pupation, Kilner jars measuring 95 x 83 cm (height x width) were used. These jars were covered with lids having a white nylon clothing material spread to the underside of their open tops (Plate 3). The nylon material provided ventillation while at the same time prevented the emerged adult thrips from escaping. Sand sterilized in an oven at 60°C for 12 hours was used as the pupation substrate. All the experiments were conducted in the laboratory at a temperature range of 24-32.5°C and relative humidity range of 39% - 60.5%.

3.2.2 Studies on the mating behaviour and incubation period of M. sjostedti

The objective of part of the studies reported here was to establish whether M. sjostedti adults exhibit any form of courtship behaviour prior to mating and the duration taken by thrips during mating. Newly emerged male and female adult thrips distinguished using their obvious differences in body size, colour and shape of abdomen were obtained by the procedure described in 3.2.3. These were released in the perspex cages in equal sex ratios. The thrips were then observed for a period of up to two hours for each group for any courtship related behaviour. The experiment was repeated six times. In all, 28 pairs were observed. 64 mating pairs of

Plate 3. Kilner jars used for pupating M. sjostedti



N - Nylon clothing material

L - Lid

F - Flowers

S - Sand

thrips were also timed using a stop watch from the start of mating upto the end to find out the length of time taken during the mating process.

Determination of the incubation period of eggs was carried out as follows: Cowpea seedlings were placed in the perspex cages as previously described. Five pairs of newly emerged adult thrips were released in the cages and removed after 14 hours. Preliminary observations had shown that thrips could oviposit within 12 hours after emergence. Seedling leaves bearing eggs were then clipped off and placed in petri-dishes lined with moistened filter paper to prevent the leaves from drying. These leaves were observed at intervals of 12 hours for a period of 6 days under a dissecting microscope for any nymphs that hatched. The hatched nymphs were counted and removed to avoid being recounted. Incubation period was estimated in days from the day of oviposition to the day of hatching. The experiment was replicated 10 times.

3.2.3 Nymphal development, pupation period and moisture requirement during pupation of *M. sjostedti*

The objective of part of the studies was to determine the different nymphal stages and to establish the length of time taken during nymphal development.

Cowpea seedlings were placed in perspex cages to which thrips were introduced. The thrips were removed after 14 hours. It was expected that they had by this time laid their eggs on the leaves of the cowpea seedlings as preliminary observations had shown. The leaves of the seedlings were then observed everyday using a hand lens for any hatched nymphs which were counted and recorded. Records of the developmental stages were taken everyday until no more nymphs were visible on the cowpea leaves. This was taken as being the time they had all gone into pupation in the soil.

In order to establish whether soil moisture was necessary during pupation and to determine the pupation period of thrips, approximately 400 gms of sand was added to each of the 12 kilner jars used in the studies. The jars were then divided into two groups of six each. To one group of jars 50 ml of distilled water was added to each jar. This amount of water had earlier been determined to render the sand just moist but not wet or water logged. To the second group of jars, no water was added. Cowpea flowers infested with third instar nymphs of thrips picked from the field were introduced into each of the jars of the two groups. The jars were then covered with lids and left for a period of approximately 14 hours after which the flowers were removed . This was to allow pupating thrips to move into the sand. The jars were then covered again. Observations were then made at 12 hour intervals for any

adults that emerged for the next eight days. Subsequently, little water was added to the jars with moistened sand at two day intervals to keep the sand moist.

When adults emerged, the kilner jars were placed inside the perspex cages and the lids removed to let out the emerged adults. Such adults always moved upwards from the kilner jars onto the walls of the perspex cages from where they would be collected using vials. Those that did not come out of the kilner jars (usually a small number) were removed by the use of a camel hair brush slightly moistened with water to make it sticky. The dates of emergence of thrips and the numbers emerged were recorded. The experiment was repeated six times.

3.2.4 Adult longevity of M. sjostedti

The objective of this study was to determine the length of time the adult thrips could survive with and without provision of food.

Nymphs were left to go into pupation using the procedure described above (3.2.3). On emerging, a known number (which varied at each instance) of male and female adult thrips were released into the perspex cages. Ten day old cowpea seedlings were introduced into these perspex cages. The numbers and sexes of adults surviving were recorded each day. The seedlings were replaced with fresh ones at intervals of 7

days to prevent the experimental thrips from combining with their progeny that may emerge. During the replacement, the seedlings were disturbed by shaking, by which process, the adult thrips jumped from the seedling onto the wall of the perspex cage while the non flying nymphs stuck firmly onto the leaves of the seedling. Any crawling nymphs observed in the perspex cages were removed. Recordings were taken until all the adults had died.

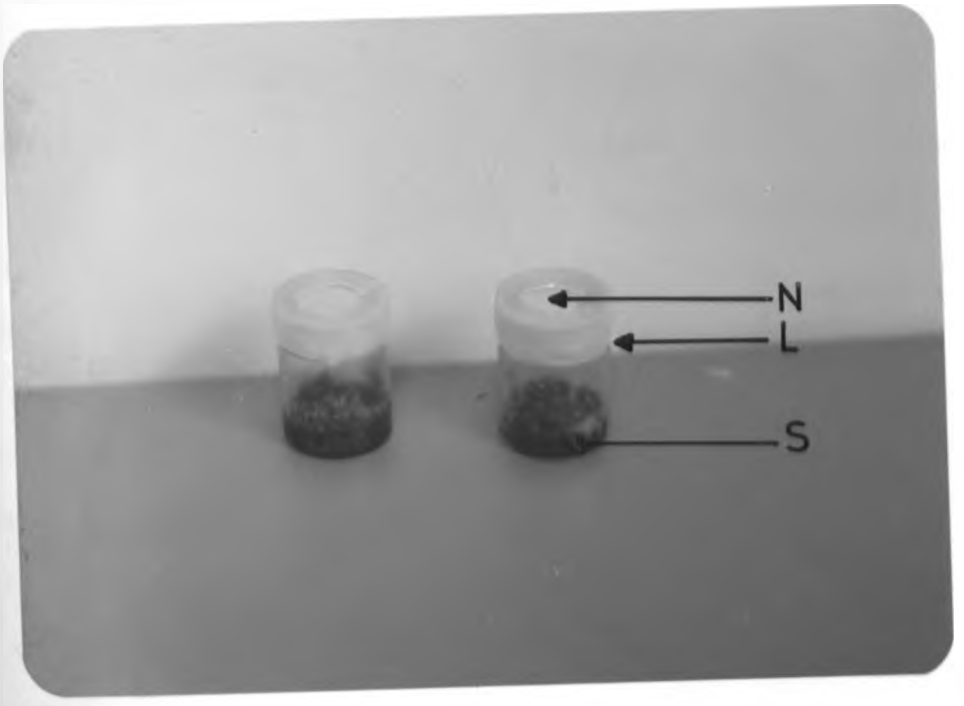
Similarly, newly emerged adults of known number and sexes were released into the perspex cages but without cowpea seedlings provided. The number of adults surviving and their sexes were recorded at intervals of 6 hours until all the adults had died.

3.2.5 Sex ratio of *M. sjostedti*

The objective of this study was to determine the sex ratio of the progeny from mated and unmated female thrips and whether parthenogenesis occurred in *M. sjostedti*.

In one experiment about 6 gms of sand was introduced into plastic vials and moistened with a few drops of water. Orange coloured nymphs (pre-pupal stage) of thrips from cowpea flowers were introduced into each of the plastic vials. The vials were then closed with lids topped with nylon clothing

Plate 4. Vials used for pupating M.sjostedti singly



N - Nylon clothing material

L - Lid

S - Sand

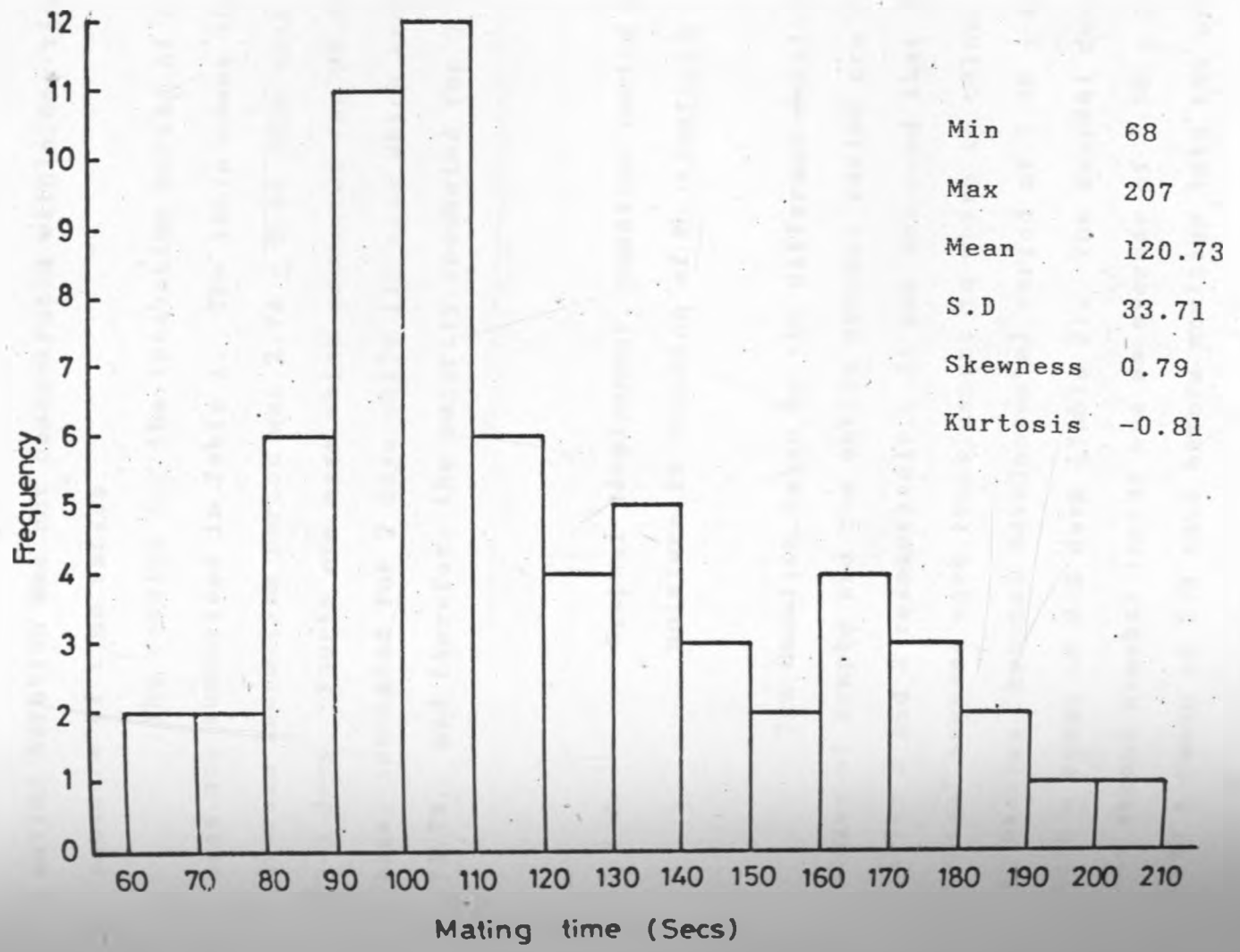
3.3. RESULTS

3.3.1 Mating behaviour and incubation period of M. sjostedti

From observations recorded in these studies, mating in M. sjostedti commenced soon after adult emergence. Apparently, no form of courtship behaviour was observed prior to mating. On meeting, which appeared to be fairly random, the male grasped the female with the forelegs before mounting her. The male then twisted its abdomen beneath that of the female. The female appeared to struggle off and in the process raised its abdomen high up. In some of the attempts the male failed to mate the female. However, when the male succeeded in the struggle, the female calmed down and they assumed a near right angle position. In addition, male thrips were observed to be promiscous and could each mate with more than one female.

The duration taken during mating by adult M. sjostedti is summarised in Fig.1 while the actual data is presented in Appendix 1. Mating in thrips lasted for an average of 120.73 $\pm$ 33.71 secs with a range of 68 - 207 secs. Fig.1 had a skewness value of 0.77, meaning that the mating duration was spread to the right of the mean. On the other hand, it showed a kurtotic value of -0.18 meaning that the mating periods were not peaked, but were rather more widespread and flat. In other words,

Fig 1. Frequency distribution histogram for mating duration taken by *M. sjostedti* adults



mating duration was not concentrated within any time range or sequence of time ranges.

The results for the incubation period of M. sjostedti eggs are summarised in Table 1. The table shows that the average incubation period was 2.74 ± 0.44 days with a range of 2-3 days. Fourty one eggs which accounted for 26.3% of the eggs, incubated for 2 days while 115 eggs which accounted for 73.7%, and therefore the majority,incubated for 3 days.

3.3.2. Nymphal development, pupation period and role of moisture in pupation of M. sjostedti

The duration taken by the different developmental stages of nymphs and the entire nymphal period are presented in Tables 2 and 3 respectively. It was observed that the first nymphal instars were transluscent to white in colour and lasted an average nymphal developmental period of 2.46 ± 0.50 days with a range of 2-3 days (Table 2). The nymphal duration for the second nymphal instar was an average of 2.55 ± 0.49 days with a range of 2-3 days before moulting into the orange coloured third nymphal instar which lasted an average of 3.29 ± 0.46 days with a range of 3-4 days before pupation (Table 2). Table 3 summarises the entire nymphal developmental period which lasted an average of 7.85 ± 0.66 days with a range of 7-10 days.

Table 1: Incubation period of M. sjostedti eggs

Number of days after oviposition.	Number of nymphs hatched	Mean incubation period ± SD
1	0	
2	41 (23.3%)	2.74 ± 0.44
3	115 (73.7%)	
4	0	
5	0	
6	0	

The number of adults emerging from the jars bearing the two sand moisture regimes are presented in Table 4. The results show that a total of 105 adult thrips, with a mean of 21 thrips per jar emerged from jars containing moistened sand while no adults emerged from all the jars containing dry sand. On removal of the dry sand, the pupating thrips were found dead and dessicated.

The pupation period of M. sjostedti when moistened sand was used as the medium is presented in Table 5. It was observed that the mean pupation period in M. sjostedti was 5.45 ± 0.83 days with a range of 4-7 days. Most of the thrips (42.7%) were observed to pupate for five days. Furthermore, thrips were observed to build pupal cells lined with silk during pupation in these studies. Thus, by considering the time ranges taken during the incubation (2-3 days), nymphal development (7-10 days) and pupation (4-7days), the entire life cycle of M sjostedti in these studies took 13-20 days.

3.5.3 Adult longevity of M. sjostedti

The number of adults surviving over a period of time with and without food are presented in Figs. 2 and 3 and Appendix 11a and 11b respectively. Adult females survived up to a period of 22 days when food was provided (Fig 2 and

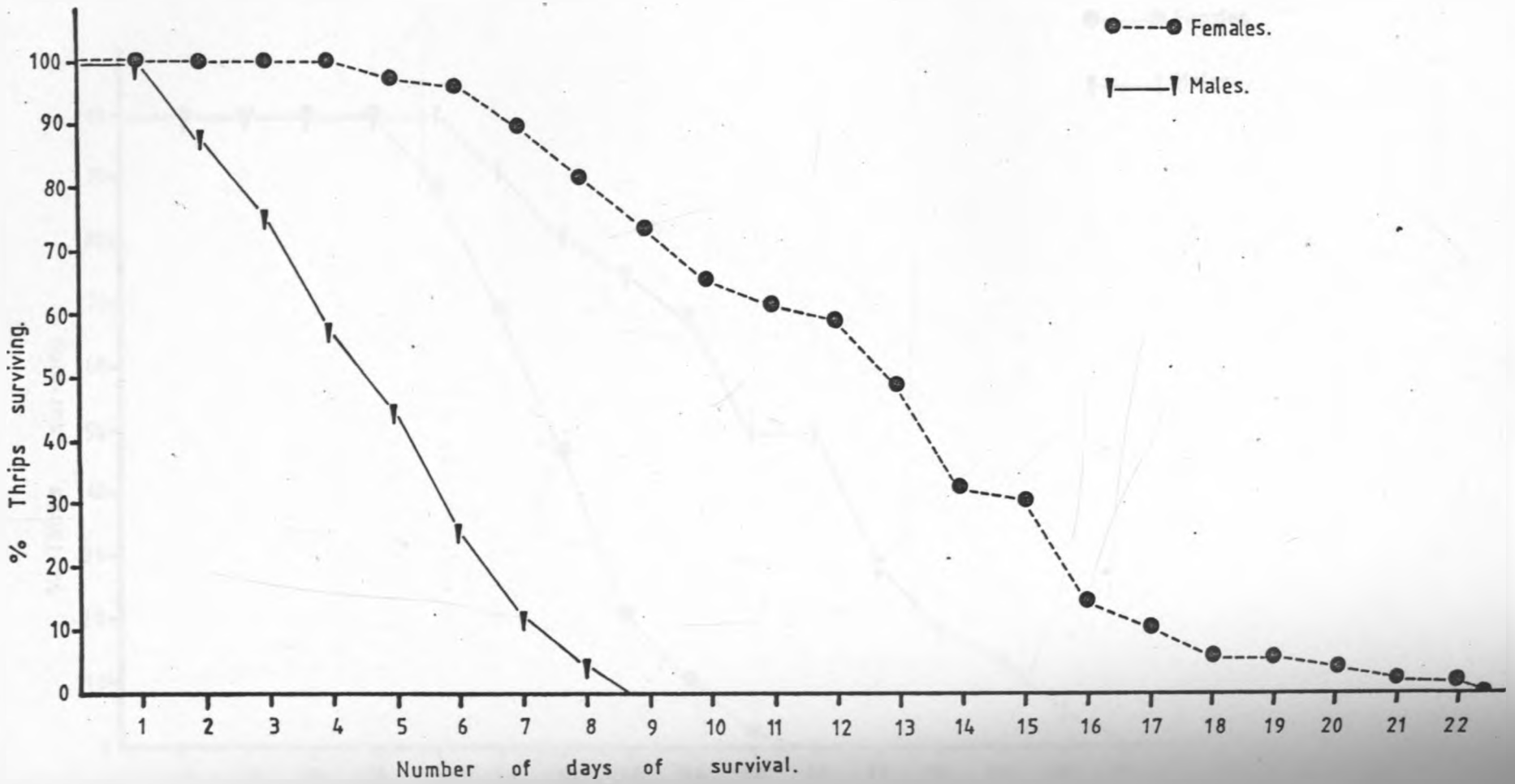
Table 4. Role of moisture in pupation of *M. sjostedti*

Moist sand		Dry sand	
Jar	No.of thrips emerged	Jar	No.of thrips emerged
a	12	a	0
b	30	b	0
c	16	c	0
d	21	d	0
e	26	e	0
Total	105		0
Mean	21		0

Table 5. Pupation period of M. sjostedti

Pupation period in days	Number of thrips observed	% of thrips observed
4	61	11.3
5	230	42.7
6	188	34.9
7	60	11.1
Total	539	100.0
Mean pupation period ± SD (days)		5.45 ± 0.83

Fig 2. Survival curve of adult M.sjostedti with food provision



Appendix 11a). Mortality of the thrips began on the fifth day when 2.04% deaths were recorded . But thereafter, mortality gradually increased and by the 13th day after emergence, 50% of the female thrips population had died. On the other hand, the males survived for a period of upto 8 days when food was provided. Unlike females, the initial mortality of males began on the second day and was about five times as much, being 11.09%. By the fifth day, slightly over half (50%) of the male population had died.

Female thrips survived for a period of upto 60 hours when food was not provided (Fig 3 and Appendix 11b). Mortality of the female thrips began between the 24th and 25th hours when 10.6% deaths were recorded. By the 36th to 42nd hours, half (50%) of the female thrips had died. On the other hand, males survived upto a period of between 90 to 96 hours (3.75 - 4 days) without food. Initial mortality occurred between the 30th and 36th hours (1.25 and 1.5 days) when 8.33% of the males died, while half (50%) of the male population had died by the 60th hour (2.5 days).

3.3.4 Sex ratio of M. sjostedti

The results for the sex ratio of the progeny from mated females and unmated females are presented in Tables 6 and 7 respectively. It is evident from Table 6 that the sex ratio of male to female was 1: 1.8. The difference between the males

Table 6. Sex ratio of thrips progeny from mated females.

Replications	Progeny recorded over 10 day period	
	Males	females
1	9	17
2	13	19
3	17	27
4	6	20
5	5	17
6	15	19
7	9	16
8	11	19
9	7	17
10	12	15
11	13	18
12	13	27
Total	130	231
Ratio	1	1.8
Mean	10.8	19.3
SD	3.68	3.88
t	5.64**	

** significant at 1% level of significance

Table 7: Sex ratio of thrips progeny from unmated females

Replications	Progeny recorded over 10 day period	
	Males	females
1	15	0
2	12	0
3	26	0
4	19	0
5	9	0
6	14	0
Total	95	0
Mean	15.8	0
SD	5.98	0

and the females was highly significant ($P < 0.01$) when data collected was compared using the paired Students t-test. Table 7 shows that the progeny from unmated females were all males in all the observations from the experiment. It was therefore concluded that female thrips predominated over males in numbers and that they are able to reproduce pathenogenetically into male progeny only. .

3.4 DISCUSSION

Riddiford (1976) noted that insects which do not feed in the imaginal stage must give high priority to early reproduction and therefore, reproductive attributes such as mating must occur shortly after adult emergence. This probably explains the observations made in the present studies in which mating in M. sjostedti commenced soon after adult emergence. This is also probably a reproductive strategy as preliminary observations had shown that thrips could lay eggs on the same day of adult emergence and therefore the neccessity for mating to take place soon after emergence to ensure laying of fertilized eggs.

Legume bud thrips tend to aggregate on their habitat, the cowpea flowers. This is evident from thrips counts in Tables 8 and 9 of Chapter 4 in which thrips counts ranged from 15.43 to 111.2 per flower. This may be a sexual strategy for mate finding as the present studies revealed that sexual interaction was fairly random and was not preceded by any form of courtship behaviour. Manning (1966) reported that insects must display a basic minimum of sexual behaviour which involves the sexes approaching and identifying one another and then copulating. This was not observed in the present investigation. However, Lewis (1973) reported that different sexes of thrips identify each other by means of tactile sensory cones in the antennae, suggesting that a sex related pheromone must be operating during sexual interactions. Furthermore, Pelikan (1951) reported that the glandular areas of the abdomen secreted a lipoid substance containing an aromatic component that soothed the excited female and discouraged it from running around while the male attempted to copulate. Although the role of sex pheromones were not investigated in the present study, they may have played part during copulation especially during the struggle between sexes reported in the present studies.

In the present study,mating was shown to last from 68 - 207 seconds. In other thrips species, mating is reported to last from 20-60 mins in Aelothripids (Buffa, 1907), 3-10 mins in Caliothripids fasciatus (Russel, 1912) and 16-18 secs in

Haplothrips verbasci (Shull, 1914). This indicates that mating behaviour is quite varied and in some cases involve very great time ranges.

The incubation period recorded for M. sjostedti eggs in the present study is fairly close to and even falls within the range to that recorded by Okwakpam (1978) of 3.04 ± 0.32 days with a range of 2-4 days for M. sjostedti in Nigeria. Furthermore, Lewis (1973) reported that generally, eggs of thrips usually hatched 2-20 days after oviposition and that the higher the temperature, the quicker the hatching. The latter factor may have caused the slight differences in the incubation periods between that recorded in the present studies and that obtained in Nigeria by Okwakpam (1978) who worked under a cooler and much narrower temperature range of 21 - 25°C.

In studies involving nymphal development of M. sjostedti, Okwakpam (1978) while referring to the nymphal instars as larval stages, recognized 3 larval developmental stages in M.sjostedti. He referred to them as first stage larvae which were silvery white in colour, second stage larvae which were creamy white and third stage larvae which were pale orange at first and later turned orange red. He also obtained an average larval period of 9.6 days with a range of 7-12 days for M. sjostedti in Nigeria which encompasses the range of 7-10 days and average of 7.85 days reported in the present studies. The differences between the average nymphal developmental

periods recorded in the present study and those reported from Nigeria (Okwakpam, 1978) may be due to the influence of differing working temperatures as suggested by Lewis (1973).

Soil moisture was found to be a very vital requirement during pupation. The implication of this condition is unknown under field situation. However, it is most likely that pupating nymphs move down into the soil to depths they perceive to have the right amount of moisture while concentrating their pupation directly beneath the cowpea plants which are sheltered from direct insolation and therefore less prone to dessication. This may be absolutely necessary for their survival which for their small size, is environmentally disadvantaged with respect to body water retention. However, evidence for their behaviour in response to soil moisture and hence survival under field situation, is lacking .

The pupation period of M. sjostedti obtained in the present studies is in conformity with or quite close to that reported by Okwakpam (1978) in Nigeria in which an average of 5.68 ± 0.19 with a range of 5-6 days was recorded for the same insect. He also recorded an entire life cycle of 16-20 days while Singh and Allen (1979) reported a life cycle of 14-18 days for M sjostedti which are also fairly close to to the range of 13 - 20 days recorded in the present studies.

Legume bud thrips were found to build pupal cells. Similar observations have been reported by other workers on

other thrips species (Bailey, 1934; Obrtel, 1963; Preisner, 1964; Lewis, 1973). It would appear that such cells could be protective against potential predators and parasites and probably against compaction with soil. However, evidence for the actual function of the pupal cell is lacking.

In the present study, female thrips were found to live longer than males when food was provided. Similar observations had earlier been reported by Seshadri (1953) and Lewis (1973) on other thrips species. It is a common biological phenomenon that females often live longer than males. This is usually due to hormonal or physiological differences between the sexes. On the other hand, male thrips were found to live longer than females when food was not provided. This appears contrary to most biological systems where females survive longer than males under conditions of starvation as the females often tend to store more fat which keep them alive much longer than males. However, an explanation to the present observation may be that the greater surface area of the females in comparison to the males may result in the former losing heat energy much faster and thus a shorter life span than the latter when there is no replenishment.

The present observations have shown that females predominated over males in numbers. Okwakpam (1978) recorded a sex ratio of 1:2.2 (male:female) from the progeny of laboratory reared M. sjostedti. Faure (1960) reported a ratio of 1 male

to 1.5 females. It would appear that more females are observed than males because females live longer as shown by the present results and those of Lewis (1973). The imbalance in sex ratios in M.sjostedti may not be a reproductive disadvantage since male thrips are promiscous and can each fertilize a number of females, a phenomenon that had also been reported by Lewis (1973).

Observations in the present study have shown that virgin females give forth to male progeny only. Other workers had earlier reported that virgin females of Thrips linarius (Zawirska, 1963), Caliothrips fasciatus (Bailey, 1933), Haplothrips verbasci (Shull, 1917) and Scirtothrips citri (Munger, 1942) produced only male offspring , whereas fertilized females produced mostly females with some males from non-inseminated eggs. Whiting (1945) and Stannard (1968) reported that female thrips were always diploid and males haploid such that males can only be derived from unfertilized eggs. This pathenogenetic reproduction may help alleviate sexual imbalances in populations where such imbalances may be great, with some female thrips reproducing without being mated.

Singh (1978) and Singh and Allen (1978) reported that two early maturing cultivars, ER-1 and ER-7 which were found to be susceptible to thrips in greenhouse tests, consistently escaped thrips damage in the field trials due to early flowering or to profuse flowering, indicating that these characters were important for thrips resistance (Singh, 1979). Other lines TVu 2870, TVu 6507 and TVu 7133 were reported as being moderately resistant to thrips (Anon, 1978). More recently, TVx 3236 was also reported as being resistant to thrips (Anon, 1982).

Studies by Nganga (1980) in Kenya on Cowpea resistance to M. sjostedti indicated that the local cowpea cultivars, Mtwapa 1 and Kakamega 1 were more resistant than another local cultivar, Katumani 1 when compared in terms of thrips burden and damage to flower buds. Apart from these studies, information on the assessment of resistance /susceptibility relationships of local cowpea cultivars to M. sjostedti in Kenya is non-existent. This study was therefore carried out to investigate the resistance of various cowpea cultivars to M. sjostedti.

4.2 MATERIALS AND METHODS

Experiment 1. Assessment of M. sjostedti population density on cowpea cultivars planted on a single planting date

In these studies, cowpea cultivars were tested in the field to assess and compare their resistance to thrips using known exotic West African resistant and susceptible checks identified by Singh (1979) and Salifu (1984). It was considered in these studies that resistant cultivars would have less infestation by thrips as compared to susceptible ones.

Twelve local cowpea cultivars, namely; ICV 1, ICV 2, ICV 3, ICV 4, ICV 5, ICV 6, ICV 10, Katumani 4, Nya'chula, Nya'mbita, Nya'milambo and Yatta 2 and two West African cultivars, namely TVu 1509 (resistant check) and Ife brown (susceptible check) were planted during the short rains of 1984. Each plot consisted of 3 rows of a single cultivar measuring 5 metres long. Spacing was 30cm within and 50cm between rows. The plots were replicated six times in a randomised complete block design. Since the study area was constantly under a cowpea crop and so there was no need of planting an earlier booster cowpea crop to ensure high thrips infestation of the experimental crop.

Sampling of flowers for thrips was conducted at 45 days after planting (DAP) and at 60 DAP. On each sampling occassion, 10 flowers were randomly picked from the central rows of each cultivar. Each flower was placed in a plastic vial containing 30% alcohol. Samples were taken between 0700 and 0900 hours when thrips were less active with the least possible disturbance to the foliage. Counting of thrips was done in the laboratory under a stereo microscope.

The contents of each vial were emptied into a petri-dish and flowers were dissected and thoroughly washed in alcohol to release the thrips. The number of thrips found were counted and expressed as mean per flower. Data obtained was subjected to square root transformation to homogenize the variance in accordance with statistical requirement (Gomez and Gomez, 1976). The transformed data were then analysed using the two way Analysis of variance test and any differences in means between the cowpea cultivars separated by the Duncan's multiple range test (DMRT).

Experiment 2. Assessment of M. sjostedti population density on cowpea cultivars planted on different planting dates to synchronize their flowering

Based on observations recorded from experiment 1 above, it was found that the test cultivars had different flowering

periods (Appendix III). It therefore became necessary to conduct an experiment whereby planting was staggered so as to synchronize their flowering periods. In this way, the different cultivars would be producing flowers at the same time so that any differences in incidence of thrips population would be due to their preference or non-preference for the cultivar other than to differences in cultivar flowering periods.

The same fourteen cultivars tested under experiment 1 were planted as before during the long rains of 1985. However, this time, the late flowering ICV 3, ICV 10, Katumani 4, Nya'chula and Nya'mbita cultivars were planted first, followed by ICV 6, Ife brown, Nya'milambo, TVu 1509 and Yatta 2 cultivars six days later and ICV 1, ICV 2, ICV 4, and ICV 5 twelve days after the first set of planting (DAFP). Sampling of flowers was conducted at 45 and 60 DAFP and the thrips were extracted, counted and data treated using the procedure described in experiment 1.

Experiment 3. Population assessment of thrips in malformed and normal flowers of ICV 4 and Yatta 2 cultivars.

Based on preliminary observations from experiment 1, it was further found that the cowpea plants attacked by M. sjostedti possessed normal and malformed flowers. Flower

malformation is known to occur when infested by thrips (Taylor, 1969, 1978). It was not known whether the two forms of flowers carried an equivalent number of thrips since, if any differences existed, this would have an effect on resistance or susceptibility expression depending on the nature of the flowers forming the majority of the sample. To ascertain this, thrips populations were assessed separately on malformed and normal flowers of ICV 4 and Yatta 2. These two cultivars were selected a priori from the field used in experiment 2. Population assessment was conducted at 55 DAFP when the plants were approximately at their peak flowering stage. The thrips were extracted and counted using the procedure described in experiment 1. Data obtained was subjected to Students t-test to find out whether any differences occurred between the two forms of flowers.

4.3 RESULTS

Experiment 1. Population density of thrips on cowpea planted on a single planting date.

Results for this experiment are presented in Table 8. Statistical analysis of the data (Appendix 1Va) showed that there were higly significant ($P < 0.01$) differences between the

Table 8. Population of *M. sjostedti* on cowpea cultivars planted on a single planting date

Cultivar	Mean number of thrips per flower	
	At 45 DAP	At 60 DAP
Nya'milambo	19.72 a	93.9
Katumani 4	19.84 a	102.9
ICV 5	21.34 ab	95.0
ICV 1	21.42 ab	107.9
Yatta 2	24.40 ab	129.2
TVu 1509	24.68 ab	125.9
ICV 2	25.20 ab	120.3
ICV 3	27.50 ab	120.4
Nya'mbita	28.26 abc	109.3
Ife brown	28.28 abc	115.0
ICV 10	28.64 abc	106.5
ICV 4	29.78 abc	105.5
ICV 6	29.92 bc	113.0
Nya'chula	37.06 c	111.2
CV	26.5%	18.9%
S.E.	3.02	8.59

Mean values followed by similar letters within columns are not significantly different at 5% level (Duncans Multiple Range Test)

cultivars sampled at 45 DAP, while there were no significant ($P < 0.05$) differences between the cultivars sampled at 60 DAP (Appendix 1Vb). Additionally, there were significant differences ($P<0.05$) in the number of thrips between the cultivars that were least preferred and those that were most preferred at 45 DAP and not at 60 DAP.

It is evident from Table 8 that at 45 DAP, Nya'milambo followed by Katumani 4 had the lowest number of 19.72 and 19.84 thrips per flower respectively, and thus, were considered the least preferred. On the other hand, Nya'chula had the highest number of 37.06 thrips per flower, and was considered the most preferred. At 60 DAP, Nya'milambo again followed by ICV 5 had the least average number of thrips per flower being 93.9 and 95.0 respectively and were considered the least preferred, while Yatta 2 had the highest, being 129.2, and was considered the most preferred.

Three cultivars, namely Nya'milambo, Katumani 4 and ICV 5 consistently appeared among the top five least preferred lines and apparently exhibited more resistance to thrips than the resistant check TVu 1509 on both sampling dates. On the other hand, ICV 6, Nya'chula and Ife brown consistently appeared among the top five most preferred .

Experiment 2. Population density of thrips on cowpea planted on different planting dates/synchronized flowering periods.

Results of the experiment on the population density of legume bud thrips with synchronized flowering periods is presented in Table 9. Statistical analysis of these results (Appendix 1Vc & 1Vd) showed that there were highly significant ($P < 0.01$) differences between the cultivars at 45 DAFP and significant ($P < 0.05$) differences at 60 DAFP. Additionally, there were significant ($P<0.05$) differences on the number of thrips per flower between the cultivars that were least preferred and those that were most preferred at both flowering dates.

It was observed that at 45 DAFP, Katumani 4 had the lowest number of 15.43 thrips per flower and was considered the least preferred, while ICV 1 had the highest number of 34.58 thrips per flower and was considered the most preferred. At 60 DAFP, Nya'mbita followed by Ife brown had the lowest number of thrips per flower being 27.80 and 28.28 respectively, and were considered the least preferred, while ICV 4 had the highest number of thrips per flower being 60.98, and was considered the most preferred.

Apart from Katumani 4 which appeared first and seventh on both sampling dates respectively, four other cultivars namely, Nya'mbita, Nya'milambo, ICV 5 and the susceptible check Ife brown,

Table 9. Population of M. sjostedti on cowpea cultivars planted on different planting dates.

Cultivar	Mean number of thrips per flower	
	At 45 DAFP	At 60 DAFP
Katumani 4	15.43 a	43.30 abc 7
Ife brown	16.02 a	28.28 a 2
Nya'mbita	17.90 ab	27.80 a 1
Nya'milambo	18.43 abc	40.51abc 4
ICV 5	20.93 abcd	35.02 ab 3
ICV 6	21.07 abcd	55.45 bc 12
ICV 10	22.37 abcd	44.50 abc 9
Yatta 2	22.47 abcd	40.87 abc 5
TVu 1509	22.90 abcd	43.30 abc 7
Nya'chula	25.30 bcd	58.57 bc 13
ICV 3	25.33 bcd	42.02 abc 6
ICV 4	26.72 cde	60.93 c 14
ICV 2	29.00 de	46.77 abc 10
ICV 1	34.58 e	54.63 bc 11
CV	26.5%	28.9%
S.E.	2.45	7.06

Mean values followed by similar letters within columns are not significant at 5% level (Duncans Multiple Range Test).

consistently appeared among the top five least preferred lines and exhibited more resistance than TVu 1509 on both sampling dates, while on the other hand, Nya'chula, ICV 1, ICV 2 and ICV 4 cultivars consistently appeared among the top five most preferred and exhibited less susceptibility than the susceptible check, Ife brown.

Comparison between the results of the first experiment to that of the second, showed that Katumani 4 , Nya'milambo and ICV 5 were the only cowpea cultivars that consistently appeared among the top five least preferred on both planting patterns, whereas, Nya'chula consistently appeared among the top five most preferred on both planting patterns. On the other hand, Ife brown was the only cultivar that appeared among the top five least preferred on one planting pattern and the top five most preferred on another.

Experiment 3. Population of thrips on malformed and normal flowers of ICV 4 and Yatta 2 cultivars.

Results for the experiment on thrips population assessment on malformed and normal looking flowers of ICV 4 and Yatta 2 cultivars are summarised in Table 10. The average number of thrips per flower obtained from ICV 4 was 33.9 in normal flowers and 60.6 in malformed flowers. For Yatta 2, the

Table 10. Population of thrips in malformed and normal flowers of ICV 4 and Yatta 2 cultivars. (N=10 for each replicate)

	ICV 4		Yatta 2	
Replications	Normal flowers	Malformed flowers	Normal flowers	Malformed flowers
1	53.9	79.4	24.1	44.6
2	30.8	39.6	17.6	42.1
3	13.6	44.4	23.9	42.3
4	20.7	42.4	19.1	52.8
5	46.2	73.9	31.3	69.8
6	38.5	83.9	43.9	32.2
Mean	33.95	60.6	26.65	47.3
S.E.	6.23	8.38	3.97	5.23
t	5.87		5.93	
P	<0.01		< 0.01	

average number of thrips per flower was 26.6 in healthy flowers and 47.3 in malformed flowers. Statistical analysis, showed that there were significant differences ($t=5.87$, $P<0.01$ and $t=5.93$, $P<0.01$) between the thrips population in malformed and normal flowers of ICV 4 and Yatta 2 cultivars respectively. It was therefore concluded that malformed flowers carried significantly greater number of thrips than normal looking flowers.

4.4 DISCUSSION

In any screening programme, consistency, repeatability and precision of results is often the most desired attribute. Results obtained from the first two experiments showed that Katumani 4, Nya'milambo and ICV 5 consistently had lower thrips counts than others under the different situations and could therefore be considered as being more resistant than others. On the other hand, Nya'chula consistently had a higher thrips count than others under the different situations and can be considered as being least resistant. Other studies in Kenya have shown ICV 1 and ICV 5 to be fairly tolerant while ICV 6 susceptible to common cowpea pests including thrips (Pathak and Olela,1986). However, further studies show that ICV 1 employs the mechanism of pest evasion to attack by cowpea pests (Pathak,pers.comm.).

The methodology used in the assessment of resistance in these experiments only allowed for the identification of non-preference mechanism of resistance. However, antibiotic activity by the cowpea plants on the dynamic thrips population may not be ruled out as a factor responsible for the lower populations of thrips on the apparently resistant cultivars. Thus, studies based on the identification of tolerance and antibiosis mechanisms of resistance to thrips need to be undertaken to back-up information obtained from the current studies.

Lack of repeatability of results in the supposedly resistant check TVu 1509 and the susceptible check Ife brown reported by Singh (1977b) and Salifu (1984) , may be explained by the fact that resistance mechanism often break down under different environmental conditions (Horber,1972; Kogan, 1975; Coppel and Mertins,1977) and may have influenced the expression of resistance and susceptibility in these West African cultivars.

The highly significant diferrences obtained between thrips numbers in malformed flowers as compared to those in normal flowers (Table 10) clearly suggest that a field evaluation technique for resistance to thrips involving random sampling of cowpea flowers and subsequent thrips counts is likely to give misleading results. Thus, samples that may include more malformed flowers will definitely have a greater number of thrips thereby exhibiting apparent susceptibility.

than a sample involving more normal flowers. Furthermore, the ratio of malformed to normal flowers at any given time may be dependent upon the relative flowering periods of the different cowpea cultivars which may ultimately influence thrips numbers depending on the dates of sampling, and thus, the proper expression of resistance or susceptibility. All these factors may have influenced the results in Ife brown, Nya'mbita and ICV 1 which exhibited appreciable levels of resistance in one case and the converse in the other. Furthermore, ICV 1, ICV 2, and ICV 4 which are early flowering/maturing types, appeared among the top five most preferred only when flowering was synchronized suggesting that time of sampling in relation to the flowering periods, had an effect on the expression of resistance or susceptibility.

This therefore requires that, a field sampling technique for the determination of resistance to thrips involving insect counts, be standardized , with the influence of sampling date relative to the different flowering periods and the nature of flowers to be sampled, forming the major considerations. This will help improve the valididity and reliablility of the results on thrips populations and thus the proper expression of resistance or susceptibility.

CHAPTER 5

YIELD LOSS ASSESSMENT OF COWPEA CULTIVARS CAUSED BY M. SJOSTEDTI

5.1 Introduction.

Resistance may be quantified through yield loss assessment in relation to pest population. Alternatively, resistance can be assessed by exposing crops to selective insecticidal treatments that would eliminate all pests except the the pest under study. The effect of the target pest on yield is then compared with that obtained from a completely protected crop. Both these methods have been variously used to assess cowpea yield losses due to M. sjostedti (Singh, 1977b; Anon, 1981, 1983; Redden and Singh, 1982).

In studies involving yield loss assessment due to thrips, Singh et al (1982) found a negative relationship between seed yield and total thrips population. Singh (1979) also reported that in yield loss studies of cowpea caused by thrips at IITA, losses of 25 - 30% were recorded in the moderately resistant line TVu 1509, whereas 90-100% yield loss occurred in susceptible cultivars. However in other studies (Anon, 1982b) it was observed that there were no significant differences in yields between a crop that received incecticide and one that did not, despite carrying significantly different thrips populations.

The purpose of this study was to:

(i) establish whether thrips cause any considerable yield reductions to cowpea.

(ii) elucidate the extent of this damage in relation to various damage parameters on various local cowpea cultivars.

(iii) determine if any significant differences occur among a range of local cultivars for the various damage parameters.

5.2 Materials and Methods

The experimental design used was split-plot design with three main plot treatments (insecticidal treatments) and fourteen sub-plot (cultivars) treatments. The experiment was replicated five times. The three main plot treatments were as follows:

(i) protected plot, which was completely protected by the application of monocrotophos at the rate of 400 g.a.i./ha during the raceme initiation stage (30 DAP) to control thrips and endosulfan at the rate of 200 g.a.i. 45 and 58 DAP to control Maruca testulalis and pod sucking hemipterans.

(ii) unprotected plot, which received endosulfan at the rate of 200 g.a.i/ha at 45 and 58 DAP to control M. testulalis and pod sucking hemipterans and thus leaving

the effect of thrips alone.

(iii) control plot, which received no insecticide applications.

The difference between the protected plot and the unprotected plot would give the effect of thrips alone (measurement of interest).

The fourteen tests cultivars (sub-plot treatments) used in the previous experiments (experiments 1 and 2 of section 4.2) were planted in single rows each measuring 5 metres long in each block. Spacing was 70 x 70 cm. with entries randomised. Thrips population, seed yield and damage parameters including numbers of dropped flowers and flower buds, percentage of malformed flowers, number of pods set, percentage of malformed pods and percentage of pods with seeds were assessed.

To verify whether the different treatments had an effect on thrips population,five flowers were randomly sampled from each row at 55DAP. Flowers and thrips were then handled following the procedure described in experiment 1 of section 4.2. Thrips numbers were expressed as average numbers per flower.

Aborted flowers and flower buds were collected and counted for each of the plants in the whole plot. Six counts were conducted from the time of flower bud formation (35 DAP) at five day intervals until the pod setting stage (65 DAP). Data obtained were expressed as the average number of dropped flowers and flower buds per plant. Likewise, malformed flowers and total number of intact flowers (both malformed and normal) were counted from six

randomly selected plants in a row at a time. This was continued during the entire flowering stage at five day intervals, making a total of five counts. Malformed flowers were expressed as a percentage over the total number of flowers counted.

When the plants had completely dried up, all pods were harvested from five plants per row. The pods were counted and expressed as average number of pods set per plant. From these pods, the number of malformed pods were counted and expressed as a percentage over the total number of pods set per plant. In addition, the number of pods with seeds were counted and expressed as percentage of pods with seeds per plant. Finally, the pods were shelled and the seeds weighed. The weights were expressed as average weight of seeds per plant. The average weight was then divided by the average number of pods set by that particular plant and expressed as the average weight of seeds per pod.

Data obtained were subjected to square root transformation. The transformed data were then analysed using split-plot analysis of variance and any differences in means separated by the Duncan's multiple range Test (DMRT) for both sub-plot and main plot treatments.

The effect of thrips per cultivar was obtained by getting the difference between the entries in the protected block and those in the unprotected plot. The effect of the latter on the damage parameters was expected to be greater than that of the former. However, the foregoing comparison was not made since it

could only have been valid if significant differences between treatments and significant interactions between cultivars and treatments occurred concurrently.

In the following results, with exception of Table 11, the Analysis of Variance tables were given in the main text since they carried the most important and referred to results. The actual data were given as appendices and were treated differently as follows.

(i) where significant interactions between treatments and cultivars occurred, the cultivars were compared for all levels of treatments.

(ii) where there were no significant interactions between cultivars and treatments, pooled means of cultivars were compared.

(iii) where there were significant differences between treatments but no significant interaction between cultivars and treatments, pooled means of treatments were compared.

5.3 RESULTS

5.3.1 Population studies of M. sjostedti on cowpea of protected, unprotected and control plots

The results for the population of M. sjostedti on cowpea of protected, unprotected and control plots are presented in Table 11. Thrips averaged 2.04 per flower in the protected plot, 4.33 per flower in the unprotected plot and 6.36 per flower in the control plot. There were significant ($P < 0.05$) differences between the thrips counts in the different treatment plots (Appendix Va). It was therefore concluded that thrips population were highest in the control plot followed by the unprotected plot and lastly the protected plot, confirming that treatments were effective.

5.3.2 Number of dropped flowers and flower buds per plant, pods set per plant and weight of seeds per plant.

The results for the above four damage parameters are summarised in Tables 12, 13, 14 and 15., Figures 4,5,6 and 7 and Appendix V b, c, d and e respectively. The results show that there were no significant ($P > 0.05$) differences between the treatments (Tables 12,13,14 & 15), indicating that the different insecticidal treatments and hence the thrips , did not have any significant effect on the four damage parameters. On the other hand, there were highly significant ($P < 0.01$) differences between the cultivars and significant($P < 0.05$) interactions between the cultivars and the treatments, indicating that

Table 11. Population of M. sjostedti on cowpea of protected, unprotected and control blocks.

Replicates	Mean number of thrips per flower		
	Protected	Unprotected	Control
1	2.77	4.33	6.10
2	1.80	5.17	8.77
3	1.23	3.67	7.23
4	2.13	4.20	5.80
5	2.26	4.30	3.93
Mean	2.04a	4.33b	6.36c
S.D.	0.57	0.54	1.79
C.V.	26.73%		
S.E.	0.71		

Mean values folowed by different letters are significantly different at 5% level.

Table 12 Analysis of variance for average number of dropped flowers per plant

Sources of variation	df	SS	MS	F
Replications	4	0.34	0.084	0.07 NS
Treatments	2	6.39	3.19	2.85 NS
Main plot error	8	8.96	1.12	
Cultivars	13	21.00	1.61	7.49 **
C X T	26	9.45	0.36	1.68 *
Sub-plot error	156	30.76	0.21	
Total	209	76.9		

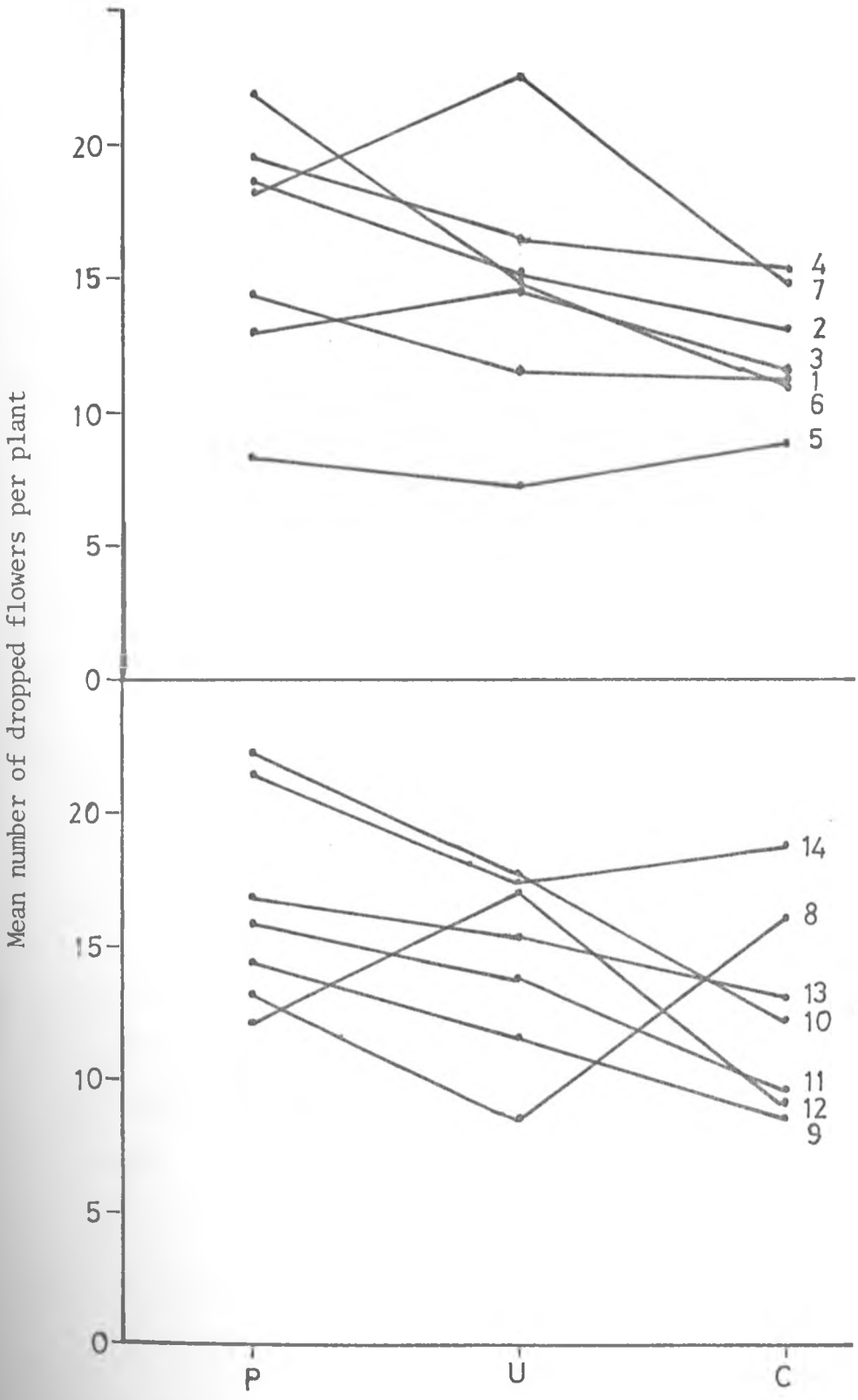
NS Not significant

** Significant at 1% level

* Significant at 5% level

CV = 12.44%

Fig 4. Cultivar X Treatment interaction plot for average number of dropped flowers per plant



1. Nyamilambo 2. Katumani 4 3. ICV 5 4. Nyambita 5. Ife brown 6. ICV 10 7. Yatta 2 8. TVu 1509 9. ICV 1 10. ICV 3 11. ICV 6 12. ICV 2 13. ICV 4 14. Nyachula

P: Protected U: Unprotected C: Control

Table 13 Analysis of variance for average number of dropped buds per plant

Sources of variation	df	SS	MS	F
Replications	4	207.2	51.8	0.35 NS
Treatments	2	89.8	44.9	0.03 NS
Main plot error	8	1185.4	147.8	
Cultivars	13	479.9	36.91	3.04 **
C X T	26	518.8	19.9	1.64 *
Sub-plot error	156	1887.6	12.1	
Total	209	4368.7		

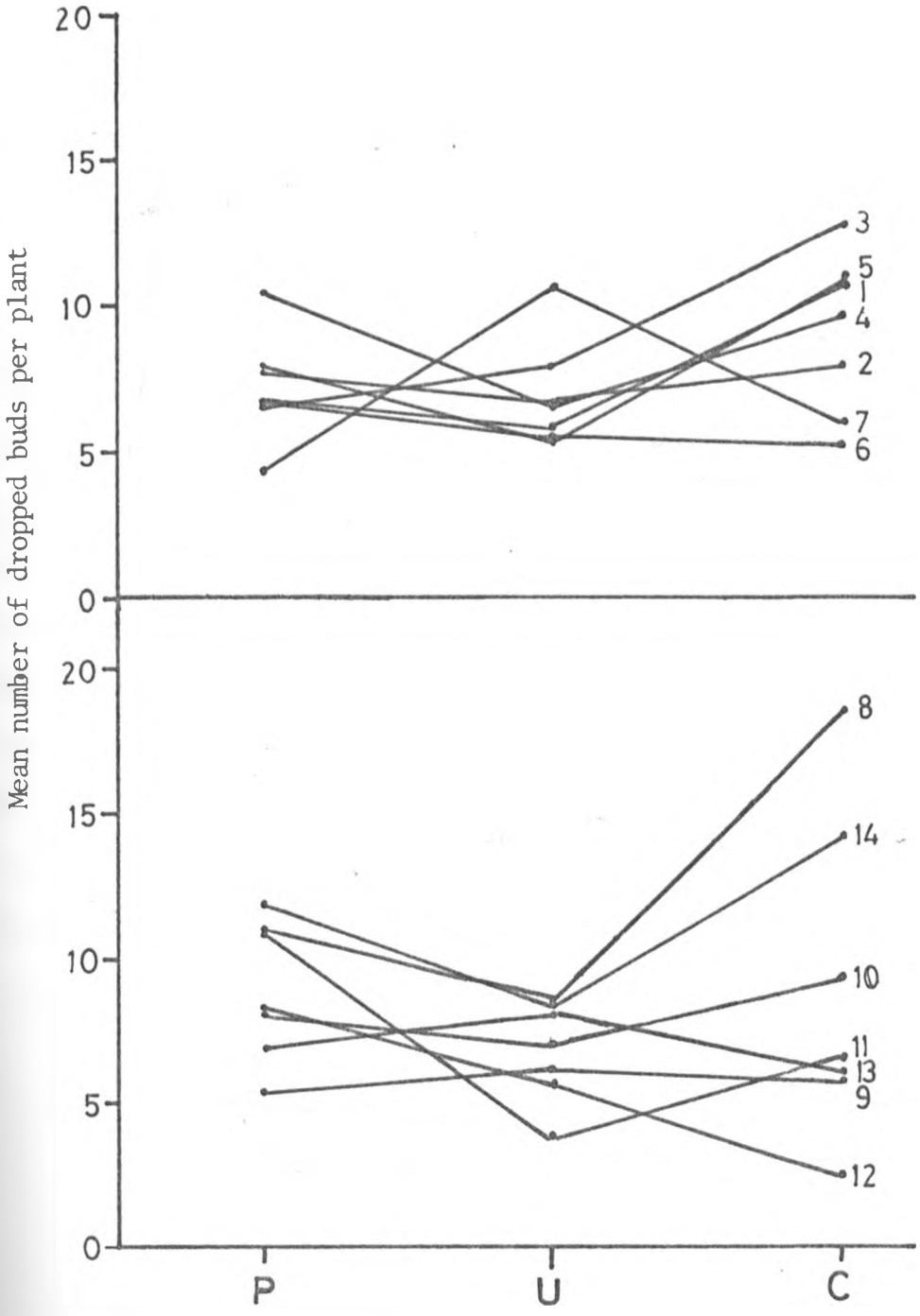
NS Not significant

* Significant at 5% level

** Significant at 1% level

CV = 14.42%

Fig 5. Cultivar X Treatment interaction plot for average number of dropped buds per plant



1. Nyamilambo 2. Katumani 4 3. ICV 5 4. Nyambita 5. Ife brown 6. ICV 10 7. Yatta 2 8. TVu 1509 9. ICV 1 10. ICV 3 11. ICV 6 12. ICV 2 13. ICV 4 14. Nyachula

P: Protected U: Unprotected C: Control

Table 14: Analysis of variance for average number of pods set per plant.

Sources of variation	df	SS	MS	F
Replications	4	4.9	1.24	0.54 NS
Treatments	2	10.5	5.25	2.27 NS
Main plot error	8	18.5	2.3	
Cultivars	13	198.5	15.3	26.04**
C x T	26	26.2	1.0	1.72 *
Sub-plot error	156	91.5	0.58	
Total	209	350.1		

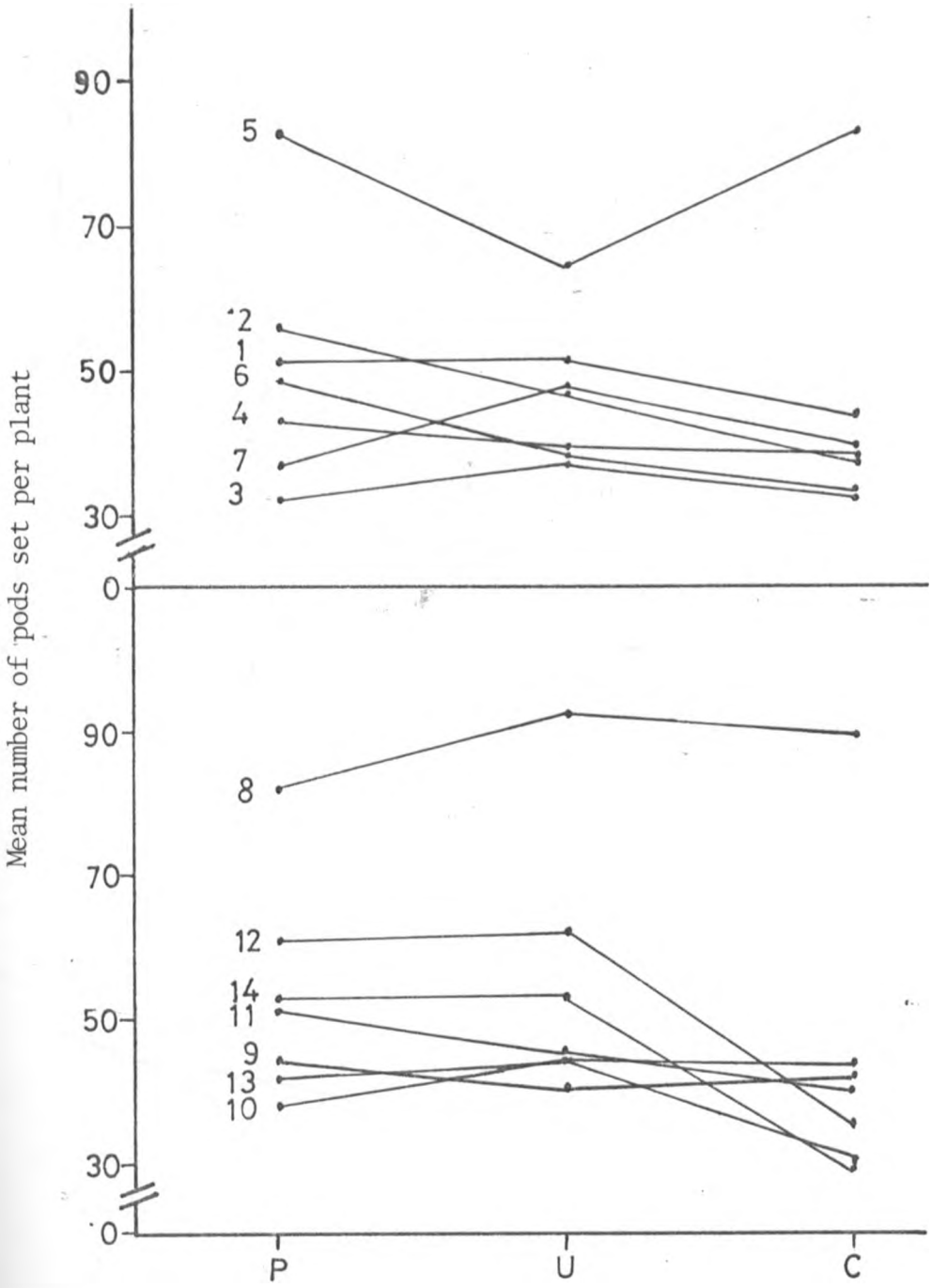
NS Not significant

** Significant at 1% level

* Significant at 5% level

CV = 11.28%

Fig 6. Cultivar X Treatment interaction plot for average number of pods set per plant



1. Nyamilambo 2. Katumani 4 3. ICV 5 4. Nyambita 5. Ife brown 6. ICV 10 7. Yatta 2 8. TVu 1509 9. ICV 1 10. ICV 3 11. ICV 6 12. ICV 2 13. ICV 4 14. Nyachula

P: Protected U: Unprotected C: Control

Table 15: Analysis of variance for average weight of seeds per plant

Sources of variation	df	SS	MS	F
Replications	4	15.72	3.92	1.30 NS
Treatments	2	5.77	2.98	0.95 NS
Main plot errpr	8	24.22	3.02	
Cultivars	13	99.10	7.62	8.61**
C x T	26	40.07	1.54	1.74*
Sub-plot error	156	138.10	0.88	
Total	209	322.98		

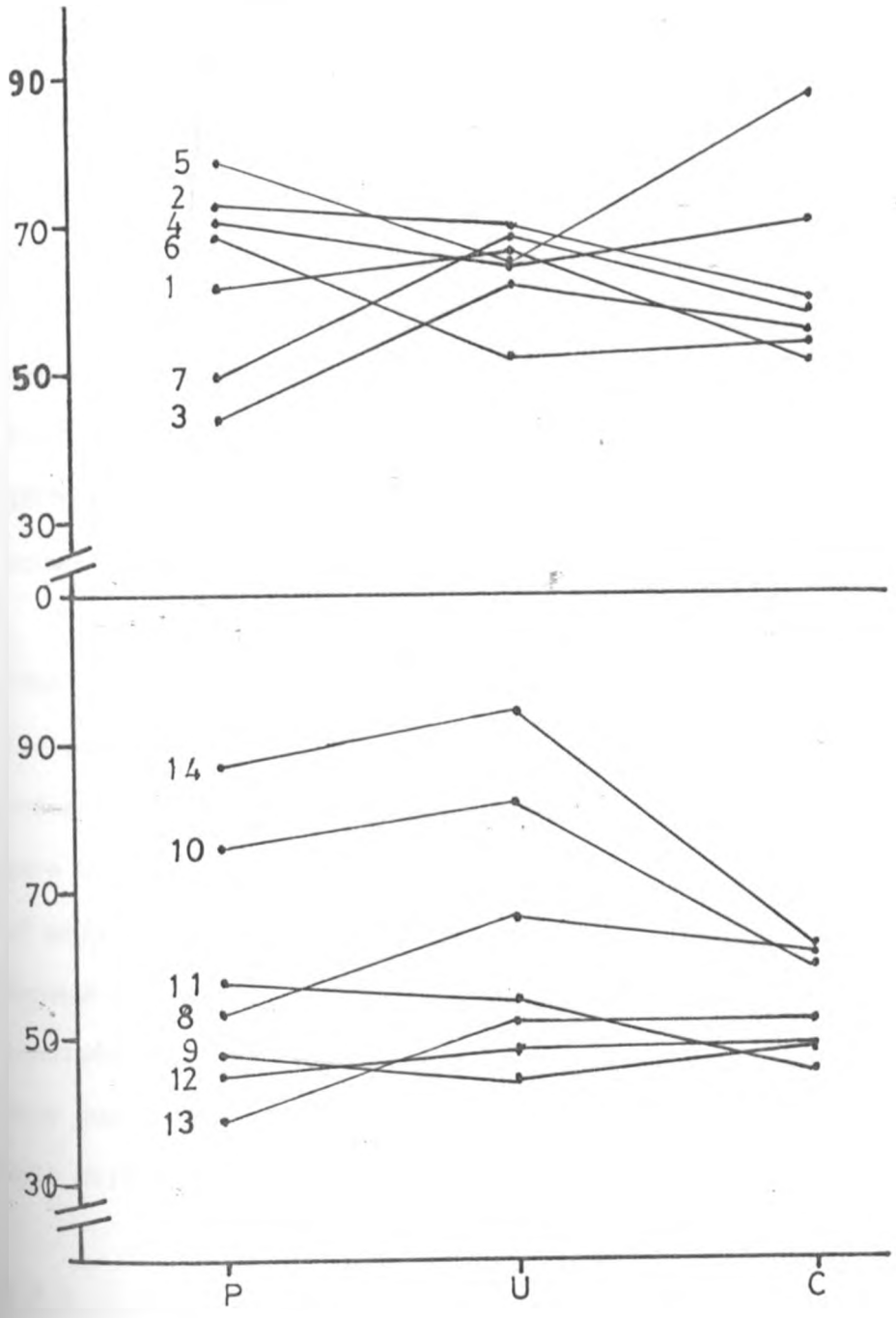
NS Not significant

* significant at 5% level

** significant at 1% level

CV = 12.25%

Fig 7. Cultivar X Treatment interaction plot for average weight of seeds per plant



1. Nyamilambo 2. Katumani 4 3. ICV 5 4. Nyambita 5. Ife brown 6. ICV 10 7. Yatta 2 8. TVu 1509 9. ICV 1 10. ICV 3 11. ICV 6 12. ICV 2 13. ICV 4 14. Nyachula

P: Protected U: Unprotected C: Control

differences between cultivars were not the same at different treatments. This interaction is shown in Figures 4,5,6 & 7 with the graphs devided into two portions based on the relative resistance or susceptibility of the test cultivars. The line graphs at the top represent the less preferred lines while those at the bottom represent the more preffered. It is evident from these figures that the different cultivars responded differently at each treatment level to thrips effect in relation to the four damage parameters. Furthermore, there appeared to be a general and consistent trend of response within and between the groups except for a few cultivars which responded differently. Such cultivars included TVu 1509 and ICV 2 in Figure 4, Yatta 2 in Figures 4 and 5 and finally Ife brown in Figures 5 and 6.

Despite lack of significant treatment effect, which previously (Table 11 and Appendix Va) had been shown to have significant effect on thrips populations, it was concluded that since there was significant interaction between the cultivars and the treatments, thrips did indeed have an effect on the numbers of dropped flowers and flower buds, number of pods set and weight of seeds per plant. However, this effect was dependent upon the cultivar at each level of treatment. It was also concluded that the highly significant differences between cultivars were only due to varietal differences, but that these differences fluctuated with different treatments.

5.3.3. Percentage of malformed flowers per plant and average weight of seeds per pod

Results for the two damage parameters are presented in Tables 16 and 17 and Appendix V f and g respectively. Tables 16 and 17 show that

Table 16: Analysis of variance for percentage of malformed flowers per plant

Sources of variation	df	SS	MS	F
Replications	4	2250.5	562.6	1.57 NS
Treatments	2	3325.3	1662.6	4.64 *
Main plot error	8	2864.7	358.1	
Cultivars	13	7354.6	565.7	12.49 **
C X T	26	785.1	30.2	0.67 NS
Sub-plot error	156	7066.4	45.3	
Total	209	23646.6		

NS Not significant

* Significant at 5% level

** Significant at 1% level

CV = 17.58%

Table 17: Analysis of variance for average weight of seeds per pod

Sources of variation	df	SS	MS	F
Applications	4	0.12	0.30	3.24 NS
Treatments	2	0.09	0.04	4.84*
Main plot error	8	0.07	0.009	
Cultivars	13	2.90	0.22	62.44**
C x T	26	0.11	0.004	1.18 NS
Sub-plot error	156	0.56	0.004	
Total	209	3.85		

NS Not significant

* significant at 5% level

** significant at 1% level

CV = 4.45%

there were significant ($P < 0.05$) differences between treatments, indicating that the insecticidal treatments and hence the thrips had significant effect on the two damage parameters. The percentage of malformed flowers averaged 30.39 in the protected plot, 40.45 in the unprotected plot and 45.44 in the control plot (Appendix Vf), while weight of seeds per pod averaged 1.23 in the protected plot, 1.34 in the unprotected plot and 1.42 in the control plot (Appendix Vg). Of the two damage parameters, only the percentage of flowers malformed conformed to the trend of thrips populations in the three treatment plots, while the converse was true for the average weight of seeds per pod (cf Appendix Va to Vf & g).

There were highly significant ($P < 0.01$) differences between cultivars. It was further noted that the early flowering cultivars like ICV 1 and ICV 2 possessed the lowest percentages of 25.32 and 25.35 malformed flowers per plant respectively, while the late flowering cultivars like ICV 3 and Nya'chula possessed the highest percentages of 48.38 and 56.74 malformed flowers respectively (cf Appendix III and Vf). There were no significant ($P > 0.05$) interactions between cultivars and treatments (Tables 16 &17), indicating that the cultivars were not significantly affected by the different treatments. In other words, the cultivars responded proportionately to the different treatments with respect to the two damage parameters. It was therefore concluded that thrips caused significant increase in the percentage of malformed flowers, while it could be superfulous to conclude that the converse was true for the average weight of seeds per pod. However, this increase in percentage of malformed

flowers, was constant or fixed for all the fourteen cultivars in relation to the treatments, with differences between cultivars only being due to varietal differences and not to thrips effect.

5.3.4 Percentage of malformed pods and pods with seeds per plant

Results for the percentage of pods malformed and percentage of pods with seeds are presented in Tables 18 and 19 and Appendix V h and i respectively. The results show that there were no significant ($P > 0.05$) differences between treatments (Tables 18 &19). It was therefore inferred that the insecticidal treatments, and hence thrips, did not have significant effect on both damage parameters. On the other hand, there were highly significant ($P < 0.01$) differences between cultivars with respect to percentage of malformed pods per plant, while there were no significant($P > 0.05$) differences between cultivars for the percentage of pods with seeds. In addition, both parameters showed no significant ($P < 0.05$) interactions between the treatments and the cultivars, indicating that differences and similarities respectively, between the cultivars, were not significantly affected by the treatments. On this basis, it was concluded that thrips did not significantly increase the percentage of pods malformed , nor did they cause significant decrease in percentage of pods with seeds. The differences between cultivars for the percentage of malformed pods were only

Table 18: Analysis of variance for percentage of malformed pods per plant.

Sources of variation	df	SS	MS	F
Replications	4	330.7	82.7	2.43 NS
Treatments	2	2.3	1.15	0.03 NS
Main plot error	8	271.8	33.9	
Cultivars	13	5776.2	444.3	26.35**
C x T	26	600.1	23.1	1.37 NS
Sub-plot error	156	2630.7	16.86	
Total	209	9611.8		

NS Not significant

** significant at 1% level

CV= 9.97%

Table 19: Analysis of variance for percentage of pods with seeds.

Sources of variation	df	SS	MS	F
Replications	4	154.9	38.7	1.28 NS
Treatments	2	77.8	38.9	1.29 NS
Main Plot error	8	242.2	30.3	
Cultivars	13	416.2	32.0	1.31 NS
C x T	26	569.8	21.9	0.9 NS
Sub Plot error	156	3798.8	24.3	
Total	209	5259.3		

NS Not significant

CV = 5.12%

due to varietal differences while the cultivars responded in a similar way or were unaffected to thrips infestation with respect to percentage of pods with seeds.

In all, the findings of this study showed that thrips were effectively controlled by insecticides as there were significant differences ($P < 0.05$) in thrips populations among the entries in the different treatment regimes. However, apart from the percentage of malformed flowers per plant, the same was not reflected on all the damage parameters assessed.

5.4 DISCUSSION

These results show that thrips did affect some of the damage parameters and that there was generally a common and consistent trend on their effect in relation to the three different treatments. This effect however, was dependent upon the cultivar. Whitney (1972) reported that thrips affected the number of pods set, percentage of pods with seeds, and weight seeds per plant and per pod. On the other hand, Anon (1982b) reported that in experiments to determine cowpea yield losses due to M. sjostedti, though there was a significant difference in thrips population between a crop that received insecticides from one that did not, the same was not reflected in the final seed yield. The

that probably the low numbers of thrips observed in the field were not able to cause considerable damage. The thrips population obtained in this study were relatively low (as compared to thrips populations obtained earlier in the experiment described in chapter 4) and could have led to the lack of any yield loss. However, this alone may not be an adequate explanation since the economic injury level of thrips is unknown and may vary depending on other environmental variables.

Singh (1979) reported that generally yield losses in cowpea are usually incurred only if there is insufficient moisture in the soil or when temperature regimes become increasingly unfavourable as the season progresses. In this study, soil moisture was not limiting as the experimental plot was planted during the long rainy season. The dry spells in between were complemented by irrigation. It could therefore be postulated that under such a condition of abundant soil moisture and relatively low thrips population, yield losses due to thrips were most unlikely.

The percentage of malformed flowers per plant was the only damage parameter that conformed to the population trend of thrips in the different treatment blocks. One notable observation was that the early maturing cultivars, namely, ICV 1, ICV 2, ICV 4 and ICV 5 had consistently lower proportion of malformed flowers

per plant than the other test cultivars. Since flower malformation is symptomatic of the intensity of attack as shown in Table 10 of the previous chapter, these four cultivars thus appeared to exhibit some form of apparent resistance. This form of resistance called pseudoresistance through host evasion, is actually known in cowpeas. Singh (1979) reported that some cowpea cultivars escaped thrips damage in field trials due to early flowering or profuse flowering and that these characters were important for thrips resistance. However, some of these early maturing, pest evading and therefore apparently resistant cultivars may be potentially susceptible espescially when grown under synchronised flowering. Therefore the assessment of resistance based on flower malformation may not represent true resistance probably only unless flowering is uniform or synchronised.

CHAPTER 6

6.1 GENERAL DISCUSSION AND CONCLUSION

The findings of the study on various aspects of the biology of M. sjostedti, adds to the pool of information generally required prior to embarking on planning a pest management programme.

The observation that M. sjostedti, essentially a pest of flower buds and flowers, oviposited and survived entirely on cowpea seedlings confirmed Taylor's (1969) report that thrips infestation began just before flowering. This implies that chemical control of thrips should start at pre-flowering stage to hinder the establishment of populations that would later infest the flowers in big numbers.

Pupation was observed to take place in the soil. Under field situation, this is apparently ensured by dropping of flowers by which process the thrips gain access to the soil. A possible cultural control of thrips would be to continuously pick up and dispose of the dropped flowers before the thrips have dislodged from the flowers to migrate into the soil to pupate. In this way, populations of subsequent generations could be minimized. However, picking of dropped flowers may not be feasible and therefore this control operation cannot be recommended for adoption by farmers. Alternatively, chemical soil treatment just

before peak flowering would be too expensive due to the large amounts required, and therefore may be unfavourable to the farmers.

Moisture was found to be highly required by thrips in the sand (soil) during pupation. This often result to their numbers rising to damaging levels just when the cowpea plant also require the the moisture for flowering and fruiting. Owing to this coincidental situation, chemical control of thrips (through foliar sprays) is recommended at this time.

The short adult longevity period observed in M. s.jostedti could imply that with proper management and manipulation of alternative hosts and volunteer crops, thrips would generally require a very short closed season to bring their populations low.

Parthenogenesis observed in M. s.jostedti nullifies the possible use of sterile insect technique control strategy since females will only produce males that will in turn mate with them to give offspring of both sexes.

This leaves us probably with the option of chemical control. However, chemical control poses great danger to both animals and the physical environment. Lewis (1973) also pointed out that chemical control of thrips is usually difficult because of great numbers that infest individual plants and the rapid increase of field population caused by breeding and airborne migrations. One logical option left is cowpea cultivars naturally resistant to thrips. The development of thrips resistant cultivars naturally capable of keeping thrips population low and thus less insecticide

applications, together with natural biological control and proper cultural practices would be an effective package for controlling thrips

Studies involving the evaluation of various cowpea cultivars for resistance to thrips revealed that there was some resistance in Katumani 4, ICV 5, and Nya'milambo cultivars. Adkisson and Dyck (1980) reported that varieties with low or moderate levels of resistance or those that may be able to evade pest attack can be used as a good advantage for pest suppression. They further reported that the key to success lies in their incorporation into management systems and other control measures that would suppress pest numbers while conserving natural enemies and that should this be achieved, the insecticides might be used more selectively and less frequently. However, recommending these three local cultivars for commercial production would be haphazard. Fine screenhouse tests are still required to determine their stability and establish their mechanisms of resistance which already appears to be either antibiosis or non preference or both. Secondly they have to be tested on their resistance to other field pests of cowpea and their yield potentials be determined before they could be recommended for the purpose of commercial production or breeding.

The existence of no cowpea seed yield losses due to thrips requires that studies should be conducted to establish the economic injury level of thrips on cowpea while considering the interacting

environmental variables like soil moisture, relative atmospheric humidity and temperature.

Cultivars or crops showing pseudoresistance through early maturity (host evasion) are important and have been used as a good advantage in economic entomology (Horber, 1980). Thus the cultivars ICV 1, ICV 2, ICV 4 and ICV 5 through their early maturity could be advantageous in economic entomology. Early maturity alone may not be a sufficient attribute as they may not exhibit their apparent resistance under a wider range of environments. However, their early maturity attribute could be incorporated into resistant and high yeilding cultivars to give an early maturing (therefore pest evading), high yielding thrips resistant cultivar.

6.2 REFERENCES

Acland, J.D. (1971). East African crops. Longman Group Limited. London. 252 pp

Adkisson, P.L. and Dyke, V.A.(1980). Resistant varieties in management systems. In: Breeding plants resistant to insects. ed. F.G. Maxwell and P.R. Jennings. John Wiley and sons, New York. pp 233-251.

Agyen-Sampong, M. (1976). Coordinated insecticide trial. Yield performance of Insect resistant cowpea cultivars from IITA compared with Ghana cultivars. Trop. Grain Legume Bull. 5:6

Agyen-Sampong, M. (1978). Pests of cowpea and their control in Ghana. In: Pest of Grain Legumes: Ecology and control. ed S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London and New York. 454 pp.

Ames, O. (1939). Economic Annuals and Human cultures. Botanic museum, Harvard University, cambridge, Mass., USA.

Anon. (1973). Grain Legume imporevement program. Annual report for 1972. IITA, Ibadan, Nigeria P. 28-40

Anon (1976). Grain Legume Improvement Program. Annual Report for 1975. IITA, Ibadan, Nigeria. 217 pp

Anon (1977). Highlights of 1976 Research. IITA, Ibadan, Nigeria. 42 pp

Anon (1978). Insect and disease resistance in cowpea. In its: Research highlights for 1977, IITA, Ibadan, Nigeria. PP 35-42

Anon (1979). Grain Legume Improvement program. Annual report for 1978. IITA, Ibadan, Nigeria. P 27-39

Anon. (1980). Integrated Control of cowpea pests. Research highlights for 1979. IITA, Ibadan, Nigeria. PP 48-49

Anon. (1981). Grain Legume Improvement program. Annual Report for 1979. IITA, Ibadan, Nigeria. PP 117-137

Anon. (1982a)..Crop Pests Research Programme. In Tenth Annual Report. ICIPE, Nairobi, Kenya.

Anon. (1982b). Grain Legume Improvement program. Annual Report for 1981. IITA, Ibadan, Nigeria. PP 128-151

Anon. (1983) Grain Legume Improvement program. Annual Report for 1982. IITA, Ibadan, Nigeria PP 53-68

Anon (1984). Grain Legume Improvement program. Anual report for 1983. IITA, Ibadan, Nigeria pp 63-83

Appert, J. (1964). Faune parasitaire du Niebe (Vigna unguiculata (L) Walp) = V. catjang (Burm) Walp). en Republique du Senegal. Agron. Trop. Nogent. 19: 788-99

Assa, D.A. (1976) Co-ordinated minimum insecticide trial. Yield performance of insect resistant cowpea cultivars from IITA. Trop. Grain Legume Bull. 5:9

Ayoade, K.A. (1969) Insecticide control of the pod-borer Maruca testulalis Gey. on Westbred Cowpea (Vigna sp). Bull Entomol. Soc. Nigeria. 2: 23-33.

Ayoade, K.A. (1975). Preliminary investigation into the effect of some insecticide sprayers on methods of application on the insect pests and yields of cowpea (Vigna unguiculata (L) Walp). Nigerian J. Entomol. 1(2): 133-141

Bailey, S.F. (1933). The biology of bean thrips. Hilgardia 7, 467-522.

Bailey, S.F. (1934). Factors influencing pear thrips abundance and effectiveness of cultural control. J. econ. Ent. 27, 879-884.

Beck, S.D. (1965). Resistance to Insects. Ann. Rev. Entomol. 10: 207-232

Bhatti, (1969). The Thysanoptera of the world. Oriental Insects 3(3) 242

Bindra, O.S. and Sagar, P (1976). Comparison of Vita-1 a pest resistant cowpea with local cultivars under different sowing dates and distance with minimal pesticide application. Tropical grain legume Bulletin No. 6. 8-19

Blackhurst, H.T. and Miller, J.C. Jr. (1980) Cowpea. Hybridization of crop plants. 327-337

Bock, K.P. (1971). Notes on East African plant virus diseases 1. Cowpea mosaic virus. East Afr. Agr. Forest. J. 37: 60-62

Bohlen, E. (1973). Crop pests in Tanzania and their control. Verlag Paul Parey,Berlin and Hamburg.

Booker, R.H. (1963). Notes on pest complex of cowpea in Northern Nigeria and a possible method of control . Paper presented at the First Nigerian Grain Legume Conference, Samaru, Zaria; Ahmadu Bello University. Inst. of Agricultural Research, P. 9-12.

Booker, R.H. (1965a). List of Insect pests found in association with cowpeas at Samaru (Northern Nigeria). Samaru Misc. Paper No. 9, 4p.

Booker, R.H. (1965b). Pests of cowpea and their control in Northern Nigeria. Bull. entomol. Res. 55(4): 663-672

Buffa, P. (1907). Trentuna specie di Tisanotteri itiliana. Atti sco. Tosc. Sci. Nat. Mem. 23. Pisa 60pp.

Burkill, T.H. (1953). Habits of man and origin of cultivated plants of the old world. Proc. Linnean Soc. London 164: 12-42

Cartwritht, W.B.; R.M. Caldwell., and L.E. Compton, (1946). Relation of temperature to the expression of resistance in wheat to Hessian fly. J. Am. Soc. Agron. 38: 259-263

Chandel, K.P.S., Joshi, B.S., and Pant, K.C. (1978). Proc. Int. Sym. Cyto-genet. and Pl. Breed. B.H.U., Varanasi, India.

Chant, S.R. (1959). Viruses of cowpea Vigna unguiculata (L). Walp in Nigeria. Ann. App. Biol. 47: 565-572

Chant, S.R. (1960). The effects of infection with tobbacco mosaic and cowpea yellow mosaic viruses on the growth rate and yield of cowpea in Nigeria. Emp. J. Exp. Agric. 28: 114-120.

Chevalier, A. (1944). Cowpea in Africa. Rev. Bot. app. Afric. trop. 633: 3.

Coppel, H.C. and J.W. Mertins, (1977). Biological insect suppression. Springer-Verlag, Berlin, 314pp

Dabrowski, Z.T., D.O.M. Bungu and R.A. Ochieng (1983). Studies on the legume pod-borer, Maruca testulalis (Geyer) 111. Methods used in screening cowpea for resistance. Insect. Sc. Application. Vol. 4, No. 1/2 pp. 141-145

Dahms, R.G. (1972). The role of host plant resistance in Integrated insect control. In: Control of sorghum shootfly M.G. Jotwani, and W.R. Young. Eds. Oxford and IBH Publishing Co., New Delhi, PP 152-167

Dahms, R.G. and R.H. Painter, (1940). Rate of reproduction of the pea aphid on different alfalfa plants. J. Econ. Entomol. 33: 482-485.

Faris, D.G. (1965). The origin and evolution of cultivated forms of Vigna sinensis. CMn. J. Genet. Cytol., 7: 433-452

Faure, J.C. (1960). Thysanoptera of Africa 3: J. ent. Soc. Sth Afr. 23: 16-44

Forsyth, J. (1966). Agricultural Insect pests of Ghana. Accra, Ghana Univ. Press. 163 pp.

Gahukar, R.T. and H.C. Chiang, (1976). Advances in European corn borer research. In: Report of the international project on Ostrinia nubilis, Phase III. Results, B. Dolinka, ed. Agricultural Research Institute of the Hungarian Academy of Sciences. Martonvasar, pp 125-173.

Ghauri, M.S.K. (1980). Notes on Anthocoridae (Heteroptera) with descriptions of two new species of economic importance from Africa. Bull. Entomol. Res., 70(2): 287-281.

Gomez,A.K. and A.A. Gomez (1976). Statistical procedures for Agricultural Research. John Wiley and sons, New York. 680pp.

Halteren, P. Van (1971). Insect pests of cowpea Vigna unguiculata (L) Walp in the Accra plains. Ghana J. Agric. Sci. 4: 121-123

Hammad, S.M. (1978). Pests of grain legumes and their control in Egypt. In: Pests of Grain Legumes: Ecology and Control. ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London and New York. 454 pp.

Hill, D (1975). Agricultural insect pests of the tropics and their control. Cambridge University Press, Cambridge, 516pp.

Holmes, N.D., Larson, L.K. Peterson and M.D. Macdonald. (1960). Influence of periodic shading on the length and solidness of the internodes of Rescue Wheat. Can J. Plant Sci. 40: 183-187

Horber, E. (1972). Plant Resistance to Insect Ag. Sci. Rev. 10:1-11

Horber, E. (1980). Type of classification of resistance. In: Breeding plants resistant to insects ed. F.G. Maxwell and P.R. Jennings. John Wiley and sons. New York.

Ingram, W.R. (1969). Observations on the pest status of bean flower thrips in Uganda. East. Afr. Agric. Forest J. 34: 482-84

Isaak, A; E.L. Sorensen and R.H. Painter (1965). Stability of resistance to aphid and spotted alfalfa aphid in several clones under various temperature regimes. J. Econ. Entomol. 58: 140-143

Jackai, L.E.N. and S.R. Singh (1983). Varietal resistance in the Integrated Pest Management of cowpea pests. Insect Sci, application Vol. 4. 4. No. 1/2 pp. 199-204

Jacot-Guillarmod, C.F. (1974) Catalogue of the Thysanopteran of the world. (Pt.3). Ann. Cape. Prov. Mus. (nat Hist.), 7(3): 517-976.

Jerath, M.L. (1968) Insecticidal control of Maruca testulalis on cowpea in Nigeria. J. Econ. Entomol. 61(2): 413-416

Johnson, N.E. (1968). Insect attack in relationship to the physiological condition of the host tree. New York Agric. Exp. stn., Ent. and Limn, Mimeo review, 1.46 pp.

Karel, A. (1977). Annual progress report. Legume program. Nairobi University, Kenya. 12 pp.

Karel, A.K. and Malinga, Y (1980). Leafhopper and aphid resistance in cowpea varieties. Trop Grain Legume Bull. No. 20: 10-11

Karny, H.W. and van Leeuwen-Reijuvaan, J. (1914) Beitrage sur Kenntnis der Gallen von Java. Sweit Mitteilung uber die Javanischen Thysanopterocecidien and deren Bewohner. Z. wiss. Insect Biol. 10: 355-69

Kayumbo, H.Y. (1975). Copea pests in Tanzania. Proc. IITA collaborators meeting in grain legume improvement. Int. Inst. Trop. Agric. Ibadan, Nigera. 1978 pp.

Kayumbo, H.Y. (1978). Pests of grian legume and their control in Tanzania. In: Pests of grain legumes. Ecology and control ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic Press, London and New York. 454 pp.

Khaemba, B.M. (1980). Resistance of cowpeas to the common pod-sucking bugs Riptortus dentipes Fabricius and Anoplocnemis curvipes Fabricus (Hemiptera:Cureidae). Ph.D. thesis, University of Nairobi. 150 pp.

Khaemba, B.M. and C.P.M. Khamala (1978) A preliminary survey of phytophagous pests of mixed cropping system of Kiambu District. In: First Annual Report of plant protection programme. ed. C.N. Karue and D.M. Mukunya. University of Nairobi, Kenya. 136pp.

Khamala, C.P.M. (1978). Pests of grain legumes and their control in Kenya. In: Pests of grain legume: Ecology and control ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London and New York. 454 pp.

Koehler, C.S. and Mehta, P.N. (1972). Relationship of insect control attempts by chemicals to components of yield of cowpeas in Uganda. J. Econ. Entomol. 65(5): 1421-1427

Kogan, M. (1975). Plant resistance in pest management. In: Introduction to insect pest management. ed. R.L. Metcalf and W.H. Luckmann. John Wiley & Sons, New York. PP. 103-146

Kyamanywa, S. (1984). Crop pests research programme In. Twelfth Annual report for 1984. ICIPE, Nairobi, Kenya. pp 5-18

Le Pelley, R.H. (1959). Agricultural insect pests of East Africa. E.A. High commission, Nairobi, Kenya. 307pp.

Lewis, T. (1973). Thrips: their biology, ecology and economic importance. Academic press, London and New York. 349pp.

Ligon, L.L. (1958). Characteristic of cowpea varieties: Vigna sinensis. Okla. Agric. Exp. Sta. Bull. 13-518

Lowe, H.J.B. (1974). Testing sugar beet for aphid resistance in the glasshouse: a method and some limiting factors. Z. Angew. Entomol. 76: 311-321

Mabonga, F.R.A. (1983). Insect pests of cowpea and studies on the cowpea yield loss assessment under different spray regimes and minimum use of insecticide against the dominant insect species at Katumani Dryland Research Station. M.sc. thesis University of Nairobi.

Macfoy, C.A. Dabrowski, Z.T. and Okech, S. (1983). Studies on the legume pod-borer Maruca testulalis (Geyer)-VI. Cowpea resistance to oviposition and larval feeding. Insect Sci. Application vol. 4 No. 1/2 pp 147-152

Macharia, G. (1984). The effect of Intercropping cowpea with maize on infestation and damage caused by the legume pod borer Maruca testulalis (Geyer) (Lepidoptera : Pyralidae) flower bud thrips Megalurothrips sjostedti

Trybom (Thysanoptera : Thripidae) and pod-sucking bugs Clavigralla shadabi Dol and Clavigralla tomentosicollis Germ (Hemiptera:Coreidae). M.sc. thesis. University of Nairobi.

Malinga, M. (1978). Resistance to cowpea aphid and leafhoppers in cowpea. M.sc thesis. Univ. of Nairobi, Kenya. 186 pp.

Manning, A. (1966). sexual behaviour. In: Insect behaviour symposia of the royal entomlogical society of London. III.ed. P.T. Haskel. Adland and sons LTD, Dorkshire, Surrey.

Maxwell, F.G. (1972). Host plant resistance to insects nutritional and pest management relationships. In: Insect and mite nutrition. ed. J.G. Rodriguez. North Holland, Amsterdam. pp. 599-609

Maxwell, F.G. and P.R. Jennings (1980). Breeding plants resistant to insects. John Wiley and sons, New York. 683 pp

McMurty, J.A. (1962). Resistance of alfalfa to alfalfa spotted aphid in relation to environmental factors. Hilgradia. 32: 501-539

Morgan, H.G. (1973). JF 2764 in the control of pod-boring insects of cowpea in southern Ghana. Ghana Farmer 17: 22-25.

Munger, F. (1942) Notes on the biology of citrus thrips. J. econ. Ent. 35, 455.

Muruli, B.I., Pathak, R.S., Mukunya, D.M., Karel, A.K. Keya, S.A.O. and Ssali H. (1980). Cowpea research in Kenya. Trop. Grain Legume Bull. Ibadan, Nigeria pp. 13-16.

Mwanze, K.P. (1971). Computer aided analysis of the morphological variation in wild and cultivated Vigna unguiculata (L) Walp from Africa. B.sc Research project. Dept. Agric. Biol. University of Ibadan, Nigeria 68 pp.

Nangju, O., Flinn, J.C. and Singh S.R. (1974) Control of cowpea pest by utilization of insect resistant cultivars and minimum insecticide application. Field crops Res. 2 (4): 373-385

Nganga, P.P. (1977). Some insect pests of importance in the coast province of Kenya during 1977. Kenya Entomol. Newsl. No. 6: 9-10

Nganga, P.P. (1980). Studies on population dynamics, seasonal incidence and control of legume bud thrips Megalurothrips sjostedti (Trybom) (Thysanoptera:Thripidae) in cowpea fields in the coast province of Kenya. M.sc thesis. University of Nairobi. 74 pp.

Nyiira, Z.M. (1971). The Status of Insect pest of cowpea, Vigna unguiculata (L) Walp in Uganda and their control. PANS Pest Artic. News Summ. 17: 194-197.

Nyiira, Z.M. (1978). Pests of grain legumes and their control in Uganda. In: Pests of Grain legumes: Ecology and control. ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London and New York. 454 pp.

Obrtel, R. (1963). Subterranean phase of metamorphosis in Odontothrips loti Hal. (Thysanoptera:Thripidae) Zool. Listy 12, 139-148.

Ochieng, R.S. (1977). Studies on the bionomics of two major pests of cowpea (Vigna unguiculata (L) (Walp): Ootheca nutabilis Sahlb (Coleoptera:Chrysomelidae) and Anoplocnemis curvipes Fabricus (Hemiptera:Coreidae). Ph.D. Thesis. University of Ibadan. Nigeria. 267 pp

Ochieng, R.S. (1978). Studies on the bionomics of Ootheca mutabilis. In: Pests of grain Legumes: Ecology and Control. ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London and New York. 454 pp.

Ochieng, R.S., Okeyo-Owuor, J.B. and Dabrowski, Z.T. (1981). Studies on the legume pod-borer Maruca testulalis (Geyer) - 11: Mass rearing on natural food. Insect Sci Application vol. 1, No. 3 pp 269-272.

Okeyo-Owuor, J.B. and R.S. Ochieng (1981). Studies on the legume pod-borer, Maruca testulalis (Geyer): Life cycle and behaviour. Insect sci application. Vol. 1, No. 3. pp. 263-268.

Okigbo, B.N. (1978). Grain legumes in the Agriculture of the tropics. In: Pests of grain legumes: Ecology and control ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press London, New York. 454 pp

Okwakpam, B.A. (1965). A preliminary checklist of West African Thysanoptera. Ibadan, Nigeria. Federal department of Agricultural Research Memorandum No. 65. 10 p

Okwakpam, B.A. (1967). Three species of thrips (Thysanoptera) in flowers in the dry season of Badeggi, Nigeria. Nigerian Entomol. Mag. 1(3): 45-46.

Okwakpam, B.A. (1978). The Taxonomy, Biology and control of two species of thrips - Megalurothrips sjostedti (Trybom and Sericothrips occipitalis (Hood (Thysanoptera:Thripidae) on legumes. Ph.D. Thesis. University of Ibadan, Nigeria, 369 pp

Ortmann, E.E. and Peters, D.C. (1980). Introduction. In: Breeding plants resistant to Insects. ed. Maxwell, F.G. and P.R. Jennings. John Wiley and sons Inc, New York. 683 pp

Painter, R.H. (1951). Insect resistance in crop plants. MacMillan, New York. 520 pp.

Painter, R.H. (1958). Resistance of plants to insects. Ann. Rev. Entomol. 3: 267-290.

Parh, I.A. (1976). A progress report on studies on the Bionomics of Empoasca spp. Associated with cowpea, Vigna unguiculata (L) Walp. Ibadan, Nigeria: Univ. Ibadan. 194 pp

Parh, I.A. (1979). Studies on the Bionomics of Empoasca spp. associated with cowpea, Vigna unguiculata L. Walp. Ph.D. Thesis. Ibadan, Nigeria. University of Ibadan. 194. pp

Pathak, M.D. (1972). Resistance to Insect pests in rice varieties In: Int. Rice. Res. Inst., Rice Breeding symposium. Los Banos, Philippines. pp. 325-341.

Pathak, M.D. and R.C. Saxena (1976). Insect resistance in crop plants. Curr. Adv. pl. sci. 8(9): 1233-1252

Pathak, R.S. and Olela J,C. (1986). Registration of 14 cowpea cultivars. Crop science, Vol.26. pp647-648

Pelikan, J. (1951). On carnation thrips Taeniothrips dianthi pr. (in czeh) Ent. Listy 14, 5-38

Phelps, R.S. and M.J. Oosthuizen (1958). Insects injurious to cowpea in Natal Region. J. ent. soc. sth. Afr., 21: 286-295

Pimentel, D (1969). Animal population, plant host resistance and environmental control Pro. Tall Timbers conf. on Ecol. Animal control by Habitat Management 1: 19-28

Piper, C.V. (1913). The wild prototype of cowpea U.S. Dept. Agric. Bul. Plant Indus. Circ. 124: 29-32

Platt, A.W. (1941). The Influence of some environmental factors on the expression of solid stem character on certain wheat varieties. Sci. Agric. 21: 139-151

Preisner, H. (1964). A monograph of the Thysanoptera of the Egyptian deserts. Publs. Inst. Desert Egypte. 13, 549 pp.

Rachie, K.O. and L.M. Roberts (1974). Grain legumes of the lowland tropics. Adv. Agron, 26: 1-132

Raheja, A.J. (1974). Report on the insect pest complex of grain legumes in Northern Nigeria. Rec. first IITA Grain Legume Improvement Workshop (1973) pp 295-299. International Institute of Tropical Agriculture. Ibadan, Nigeria.

Raheja, A.J. (1976). Co-ordinated minimum insecticide trial. Yield performance of insect resistant cowpea cultivars from IITA compared with Nigerian cultivars. Trop Grain Legume Bull 5:5

Raman, K.V., Singh, S.R. and van Emden, H.F..(1978). Yield losses in cowpea following leafhopper damage. J. econ. entomol. 71:936-938

Rawal, K.M. (1975). Natural hybridization among wild, weedy and ciltivated Vigna unguiculata (L) Walp. Euphytica 24: 699-707.

Redden, R.J. and S.R. Singh (1982). Grain Legume improvement program. In Annual Report for 1981. IITA, Ibadan, Nigeria. pp 127-151

Reddy S.K.V. (1984). Crop Pest Research programme. In Twelfth Annual Report for 1984. ICIPE. Nairobi, Kenya. pp. 5-18

Riddiford, L.M. (1974). The role of hormones in the reproductive behaviour of female wild silkworms. In: Experimental analysis of insect behaviour. ed. Browne,L.B. Springer verlag, Berlin,Hiedelberg, New York. pp278-285.

Roberts, D.W.A. and Tyrell, C. (1961). Sawfly resistance in Wheat. IV. some effects of light intensity on resistance. Can. J. Plant sci. 41: 451-465.

Roberts, M.S. and Chipeta, F.M. (1972). The effects of an insecticide spraying trial on the yield of cowpeas. Res. Bull. Bunda. Coll. Agri. Univ. Malawi 4: 24-31

Robertson, D.G. (1963). Cowpea virus research in Nigera. Proc. first Grain Legume Conference. First Agric. Res. Samaru, Zaria, Nigeria: 75-76 (mimeograph)

Roesingh, C. (1978). A progress report on resistance of legume bud thrips in cowpea. IITA, Nigeria. Unpublished.

Roesingh, C. (1980). Resistance of flower thrips Megalurothrips sjostedti (Trybom) in cowpea. Ph.D. Thesis. University of Homenhein, Stutgart.

Rogers, R.R. and R.B. Mills (1974). Reactions of sorghum varieties to maize weevil infestation under three relative humidities. J. Econ. Entomol. 67:692

Russel, H.M. (1912). The bean thrips (Heliothrips fasciatus Perganda). Bull. Bir. Ent. U.S. Dept. Agric. 118, 49 pp

Salifu, A.B. (1982). Biology of cowpea flower thrips and host plant reistance. M.sc Thesis. University of Ghana. 115 pp

Salifu, A.B. (1984). A screenhouse technique for evaluating cowpea resistance to cowpea flower thrips Megalurothrips sjsostedti (Trybom) Tropical Grain Legume bulletin. No. 29. P7-13

Sellschop, J.P.F. (1962). Cowpeas, Vigna unguiculata (L) Walp. Field crop abstr. 15: 259-266

Seshadri, A.R. (1953). Observations on Trichnothrips breviceps (Bagnall), a little known predatory thrips from South India. Indian J. Agric. Sci. 23, 27-39.

Shimura, I. (1972). Breeding of chesnut varieties to chesnut gall wasp Drycosmus kuriphilus Yasumatsu. Japan. Agric. Res. Quart. 6: 224-230

Shoyinka, S.A. (1974) Status of virus diseases of cowpea in Nigeria proc. Workshop on Grain Legume Improvement. International Institute of Tropical Agriculture. Ibadan, Nigeria, 325 pp.

Shull, A.F. (1914). Biology of the Thysanoptera. 11 sex and the life cycle. Ann. Nat. 48, 236-247.

Shull,A.F. (1917). Sex determination in Anthrothrips verbasci. Genetics 2, 480-488.

Singh, P (1970). Host plant nutrition and composition effects on Agricultural pests. Inform. Bull Belleville Res. Inst. Canada Dept. Agric. 6, 102 pp

Singh, S.R. (1973) Entomological research activities at IITA. In: Proceedings of the first IITA Grain Legume Improvement Workshop 29th Oct.-2 Nov. 1973. Ibadan, Nigeria. pp. 279-281

Singh, S.R. (1975). Entomological research activities at IITA. In: Proceeding of the first grain Legume Improvement workshop, International Institute of Tropical Agriculture, Ibadan, Nigeria, 325 pp.

Singh, S.R. (1976). Co-ordinated minimum insecticide trial. Yield performance of insect resistant cowpea cultivars from IITA compared with Nigerian cultivars. Tropical Grain Legume Bulletin. 5:4

Singh, S.R. (1977A). Grain Legume Entomology. Training booklet. Int. Inst. Trop. Agric. Ibadan, Nigeria 51 pp.

Singh S.R. (1977b). Cowpea cultivars resistant to insect pest in world germplasm collection. Trop. Grain Legume Bull. 9,3-7

Singh, S.R. (1978). Resistance to pests of cowpea in Nigeria. In: pests of Grain Legumes: Ecology and Control ed. S.R. Singh, H.F. van Emden and T.A. Taylor. Academic press, London New York. 454 pp

Singh, S.R. (1979). Biology of cowpea pests and potential for host plant resistance. Paper presented at the annual research conference of the Int. Inst. Trop. Agric., Ibadan, Nigeria, 43 pp

Singh, S.R. (1980). Biology of cowpea pests and potential for host plant resistance. In: Texas Agric. Exp. Stn. Miscellaneous publication no 1451, pp 398-421

Singh, S.R. and Allen, D.J. (1978). Pests, diseases, resistance and protection in Vigna unguiculata (L) Walp. Proc. Int. Legume Conference. London, July 23-4 August.

Singh, S.R. and Allen, D.J. (1979). Cowpea pests and disease. IITA, Ibadan, Nigeria. 133 pp.

Singh, S.R. and T.A. Taylor (1978). Pests of grain legumes and their control in Nigeria. In: Pests of grain legumes. Ecology and control. ed. S.R. Singh, H.F. van Emden and T.A. Taylor Acedemic press, London and New York 454 pp

Singh, S.R., Van Emden, H.F. (1979). Insect pests of grain legumes. Ann. Rev. Entomol. 24: 255-278

Singh, S.R., Van Emden, H.F. and Taylor, T.A. (1978). Pests of Grain Legumes: Ecology and control. Academic Press. London and New York. 454 pp.

Smarrt, J. (1976). The evolution of pulse crops. Economic botany. 32, 185-198

Snelling, R.O. (1941). Resistance of plants to insect attack. Biol. Rev. 7: 543-586

Stannard, L.J. (1968). The thrips or Thysanoptera of Illinois. Bull. Ill. st. nat. Hist. surv. 29, 2.5-552

Steel, w.m. (1976).Cowpeas Vigna unguiculata. In: Evolution of Crop plants.ed. Simmonds , N.W. Longmans, London. 183-185.

Strassen, R.Z. (1981). The food plants associations and distribution of thrips on some islands in the cape verde Archepelago (Insecta:Thysanoptera) Senckenbergiana Bilogica. 62 (4/6) 295-312

Strassen, R.Z. (1982). Thysanopterological notes (6) (Insecta:Thysanoptera) Senckenbergiana Biological. 63 (3/4) 191-209

Suh, J.P. and Simbi, C.O. (1983). Studies on the legume pod-borer Maruca testulalis (Geyer) - VIII. Cowpea phenology and yield loss assessment: Effect of loss of leaves, shoot, flowers and pods on cowpea yield in Western Kenya. Insect science and its application. Vol. 4. No. 1/2. P 89-96

Summerfield, R.J. Huxley, P.A. and Steel, W. (1974). On cowpea Vigna unguiculata (L) Walp. Field crop Abstracts 27 (7). 301-312.

Ta'ama, M. (1983). Yield performance of thrips resistant cultivars under no insecticide application. Trop. grain legume Bull. No. 27, 26-28.

Taylor, T.A. (1963). The field pest problems of cowpeas in southern Nigeria. Proc. First Nigerian Grain Legume Conference. Inst. Agric. Res., Samoru, Zaria, Nigeria. 1-8

Taylor, T.A. (1964). The problem pests sof cowpeas Vigna sinensis L. In southern Nigeria. The Nigerian Grower and Producer, 3: 17-21

Taylor, T.A. (1965). Observations on the bionomics of Lasyperesia ptychora Meyr infesting cowpea in Nigeria. Bull. Entomol. Res. 55: 761-774

Taylor, T.A. (1967). The bionomics of Maruca testulalis Gey, a major pest of cowpea in Nigeria. J. West. Afr. Sci. Assoc. 12: 111-129.

Taylor, T.A. (1968). The effects of Insecticide application on insect damage and performance of cowpea in Southern Nigeria. Nigerian Agric. J. 5: 29-37

Taylor, T.A. (1969). On the population dynamics and flight activity of Taeniothrips sjostedti (Trybom) (Thysanoptera:Thripidae) on cowpea. Bull Ent. Soc. Nigeria 2: 60-71

Taylor, T.A. (1971) Insect pest of tropical grain Legumes. Seminar on plant protection of tripical food crops. IITA/IRAT/Ford Foundation. Ibadan, Nigeria. May 24-28. 19 pp

Taylor, T.A. (1974). On the population dynamics of Taeniothrips sjostedti (Trybom) (Thysanoptera:Thripidae) on cowpea and on alternative host Centrosoma pubescens Benth., Nigeria. Rev. Zool. Afr., 88(4): 689-702

Taylor, T.A. (1978). Maruca testulalis. An. Important pest of tropical grain legumes. In pests of Grain Legumes: Ecology and control ed. S.R. Singh., H.F. van Emden and T.A. Taylor. Academic press. London and New York. 454 pp.

Taylor, T.A. and Ezedinma, F.C.O. (1964). Preliminary investigations on field pests of cowpeas and method of control. Nigerian Agric. J. 1(1):8-11

Taylor, W.E. (1976). Co-ordinated minimum insecticide trial. Yield performance of insect resistant cowpea cultivars from IITA compared with Sierra Leone cultivars. Trop Grain Legume Bull. 5:7

Van Emden, H.F. (1966). Plant resistance to insect induced by environment. Scient. Hort. 18: 91-102

Vavilov, N.I. (1951). The origin, variation, immunity and breeding of cultivated plants. Chronica Botanica 13. (1949-1950),1-364.

Watt. G. (1908). In commercial products of India Murray, London

Way, M.J. and Murdie, G. (1965). An example of varietal variations in resistance of Brussels sprouts. An. Appl. Biol. 56: 326-328

Whiting, P.W. (1945). The evolution of male haploidy. Q.Rev. Biol. 20, 231-260.

Whitney, W.K. (1972). Observations on cowpea (Vigna unguiculata (L) Walp) insects at the International Institute of Tropical Agriculture. Ibadan, Nigeria, 44pp. (mimeograph)

Whitney, W.K. and Sadik, S. (1972). Thrips damage to cowpea. Abstract of paper presented at the 2nd Annual Conference of the Nigerian society for plant protection, Ibadan, 14-16 Feb. 1972. Nigeria society for plant protection occassional publication. No. 1:9

Whitney, W.K. and Gilmer, R.M. (1974). Insect vectors of cowpea mosaic virus in Nigeria. Ann. Appl. Biol. 77: 17-21.

Wien, H.C. (1979). The use of ethephon (2-Chloroethyphos-phonic acid) to screen for abscission resistance among cowpea (Vigna unguiculata) cultivars. Plant Physiol (Bethseda), 63(5): 92.

Wien, H.C. and Tayo, T.O. (1978). The effect of defoliation and removal of reproductive structures on growth and yield of tropical grain legumes. In: Pests of Grain Legumes: Ecology and control. ed. S.R. Singh, H.F. can Emden and T.A. Taylor. Academic press, London and New York. 454 pp

Wien, H.C. and Roesingh, C. (1982). Ethylene evolution by thrips infested cowpea provides a basis for thrips resistance spraying with etephon sprays. Nature. U.K. (1980). 283(5743) pp. 192-194

Wight, W.F. (1907). The History of cowpea and its Introduction into America. U.S.D.A. Bur. Plant Indust. Bull. 102

Wilson, J.W. and Genung, W.G. (1957). Insect problems in the production of Southern peas (cowpeas). Proc. Fla. State. Hortic Soc. 69: 217-223.

Wood, E.A. Jr. and Starks, K.J. (1972). Effect of temperature and host plant interaction on the biology of three biotypes of the green bug. Environ. Entomol. 1: 230-234.

Zawirska, 1 (1963). A. contribution to the bionomics of Thrips linarius uzel (in polish Biol. Inst. Ochr. Rosl. 19, 1-10. Rev. app. Ent. (A) 52, 429.

Zhukovskii, P.M. (1962). Cultivated plants and their wild relatives (trans. P.S. Hudson). Comm. Bur. Pl. Br., Cambridge, UK.

6.3 APPENDIX

Appendix 1: Length of time taken during copulation by M. sjostedti adults

Time (Secs)												
97	94	148	169	133	95	87	175	68	103	141	92	178
107	78	198	117	122	99	98	122	115	125	75	112	177
68	184	91	146	117	88	137	126	100	168	107	207	190
140	90	132	98	97	132	103	160	90	84	83	153	99
168	163	109	106	102	107	109	105	109	117	116	101	

No. of cases	64.0	Total(secs)	7727.0
Minimum	68.0	Maximum	207.0
Mean	120.73	Variance	1136.7
S.D	33.71	S.E	4.21
Skewness	0.79	Kurtosis	-0.81

Appendix 11a: Adult longevity of M. sjostedti with food provision.

Days of survival	Numbers observed			
	Females	% mortality	Males	% mortality
1	49	0	42	0
2	49	0	37	11.90
3	49	0	32	23.80
4	49	0	24	42.85
5	48	2.04	19	54.76
6	47	4.08	11	73.81
7	44	10.20	5	88.09
8	40	18.37	2	95.23
9	36	26.53	0	100.00
10	32	34.64	0	
11	30	38.77	0	
12	29	40.82	0	
13	24	51.02	0	
14	16	67.34	0	
15	11	77.55	0	
16	7	85.70	0	
17	5	89.79	0	
18	3	93.88	0	
19	3	93.88	0	
20	2	95.92	0	
21	1	97.96	0	
22	1	97.96	0	
23	0	100.00	0	

Data summarised from six replications

Appendix 11b: Adult longevity of M. sjostedti without food provision.

No. of hours of survival	Numbers Observed			
	Females	% mortality	Males	% mortality
6	47	0	48	0
12	47	0	48	0
18	47	0	48	0
24	47	0	48	0
30	42	10.60	48	0
36	33	29.79	44	8.33
42	22	53.19	39	18.75
48	10	78.72	36	25.00
54	5	89.36	33	31.25
60	1	97.87	24	50.00
66	0	100.00	24	50.00
72	0		14	70.83
78	0		9	81.25
84	0		7	85.42
90	0		3	93.75
96	0		0	100.00

Data summarised from six replications

Appendix III. Flowering period of the test cultivars.

Cultivars	Flowering period (days after emergence)
ICV 1	28
ICV 2	28
ICV 4	28
ICV 5	30
ICV 6	34
Yatta 2	34
Ife brown	35
Nya'milambo	35
TVu 1509	35
Katumani 4	40
ICV 10	40
Nya'Mbita	40
ICV 3	41
Nya'chula	41

Appendix IVa. Analysis of variance for population of M. sjostedti planted under uniform planting regime, sampled at 45 DAP

Sources of variation	df	ss	MS	F
Cultivars	13	16.52	1.27	3.05**
Replications	5	12.11	2.42	5.81**
Error	65	27.04	0.42	
Total	83	55.67	4.11	

**Significant at 1% level

CV = 12.91%

Appendix 1Vb. Analysis of variance for population of *M. sjostedti* planted under uniform planting regime, sampled at 60 DAP

Sources of variation	df	ss	MS	F
Cultivars	13	18.2	1.40	1.38 NS
Replications	5	7.7	1,54	1.52 NS
Error	65	65.8	1.01	
Total	83	91.8	3.95	

NS = Not significant
CV = 9.62%

Appendix IVc. Analysis of variance for population of *M. sjostedti* planted under staggered planting regime, sampled at 45 DAFP

Sources of variation	df	ss	MS	F
Cultivars	13	22.53	1.73	4.30**
Replications	5	3.95	0.79	1.96NS
Error	65	26.18	0.43	
Total	83	52.66	2.92	

** significant at 1% level

NS Not significant

C.V. 13.51%

Appendix IV d. Analysis of variance for population of *M. sjostedti* planted under staggered planting regime, sampled at 60 DAFP.

Sources of variation	df	ss	MS	F
Cultivars	13	44.63	3.43	2.11 *
Replications	5	17.60	3.52	2.21NS
Error	65	103.68	1.59	
Total	83	165.91		

* Significant at 5% level
NS Not significant
CV = 19.52%

Appendix Va . Analysis of variance for population of thrips in protected, unprotected and control plots

Sources of variations	df	ss	MS	F
Replications	4	5.01	1.25	0.97
Treatments	2	46.89	23.44	18.20**
Error	8	10.31	1.28	
Total	14	62.20		

** Significant at 1% level

CV 26.73%

Appendix Vb: Average number of dropped flowers per plant

Cultivar	Protected	Unprotected	Control
Nya'milambo	14.46 bcd	11.48 bcd	11.25 bc
Katumani 4	18.57 abc	15.03 b	13.07 abc
ICV 5	13.89 bcd	14.46 bc	11.37 bc
Nya'mbita	19.44 ab	16.34 ab	15.17 abc
Ife brown	8.34 d	7.15 d	8.71 c
ICV 10	21.95 a	14.71 bc	10.95 bc
Yatta 2	18.12 abc	22.56 a	14.90 abc
TVu 1509	13.15 bcd	8.47 cd	16.07 ab
ICV 1	14.41 bcd	11.78 bcd	8.45 c
ICV 3	22.22 a	17.95 ab	13.13 abc
ICV 6	15.86 abc	13.85 bc	9.61 bc
ICV 2	12.13 cd	17.04 ab	9.22 c
ICV 4	16.98 abc	15.35 b	13.06 abc
Nya'chula	21.43 a	17.46 ab	18.77 a
Pooled means	16.49 a	14.54 ab	12.40 b
CV	12.44%		
S.E.	0.28		

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vc: Average number of dropped buds per plant

Cultivar	Protected	Unprotected	Control
Nya'milambo	6.67 ab	5.73 a	10.70 bcd
Katumani 4	7.80 ab	6.73 a	7.87 bcde
ICV 5	6.53 ab	7.86 a	12.73 abc
Nya'mbita	10.5 ab	6.46 a	9.60 bcd
Ife brown	7.73 ab	5.27 a	10.80 bcd
ICV 10	6.67 ab	6.60 a	5.07 de
Yatta 2	4.33 b	10.46 a	5.93 de
TVu 1509	11.00 ab	8.46 a	18.47 a
ICV 1	5.33 ab	6.07 a	5.60 de
ICV 3	8.00 ab	7.00 a	9.20 bcd
ICV 6	10.93 ab	3.73 a	6.53 cde
ICV 2	8.20 ab	5.47 a	2.47 e
ICV 4	6.90 ab	8.00 a	5.87 de
Nya'chula	11.8 a	8.20 a	14.20 ab
Pooled means	8.02 a	6.86 a	8.93 a
C.V.	14.42%		
S.E.	0.92		

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vd: Average number of pods set per plant

Cultivar	Protected	Unprotected	Control
Nya'milambo	51.28 bc	51.48 c	44.68 b
Katumani 4	56.20 bcd	47.16 c	37.36 bc
ICV 5	32.32 d	37.80 c	32.08 bc
Nya'mbita	42.92 bcd	39.04 c	37.52 bc
Ife brown	83.83 a	64.72 b	83.84 a
ICV 10	48.64 bc	38.32 c	33.87 bc
Yatta 2	36.96 cd	47.52 c	39.52 bc
TVu 1509	82.12 a	92.60 a	89.84 a
ICV 1	44.36 bcd	40.16 c	41.92 b
ICV 3	41.92 bcd	44.56 c	29.00 c
ICV 6	51.00 bc	45.48 c	40.00 bc
ICV 2	41.00 bcd	42.44 c	35.04 bc
ICV 4	38.04 cd	44.80 c	43.04 b
Nya'chula	53.92 b	53.28 bc	33.00 bc
Pooled means	50.25 a	49.24 a	44.33 a
C.V.	11.28%		
S.E.	0.340		

Values followed by similar letters within columns are not significantly different at 5% level of significance (Duncans multiple range test).

Appendix Ve: Average weight of seeds per plant

Cultivar	Protected	Unprotected	Control
Nya'milambo	61.74 b-e	66.61 bcd	50.98 bcd
Katumani 4	72.63 abc	69.37 bc	59.34 bc
ICV 5	43.61 ef	62.51 bcd	55.32 bcd
Nya'mbita	70.38 a-d	64.99 bcd	70.40 ab
Ife brown	78.92 ab	64.67 bcd	87.53 a
ICV 10	68.17 a-d	52.54 cd	54.55 bcd
Yatta 2	50.69 def	68.18 bc	58.32 bc
TVu 1509	53.75 c-f	66.17 bc	61.60 bc
ICV 1	48.65 def	44.31 d	48.19 cd
ICV 3	75.90 ab	82.09 ab	59.54 bc
ICV 6	58.53 b-e	55.25 cd	45.16 cd
ICV 2	45.61 ef	48.81 cd	48.32 d
ICV 4	39.40 f	52.98 cd	52.11 bcd
Nya'chula	87.79 a	94.50 a	60.88 bc
Pooled means	61.12 a	63.78 a	58.01 a
C.V.	12.25%		
S.E.	0.42		

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vf: Percentage of flowers malformed per plant

Cultivar	Protected	Unprotected	Control	Pooled means
Nya'Milambo	32.43	41.36	57.68	43.82 a-d
Katumani 4	37.35	39.09	52.10	42.85 a-d
ICV 5	22.11	25.87	36.77	28.88 bcd
Nya'Mbita	39.45	47.91	51.24	46.20 abc
Ife brown	37.31	44.63	44.27	42.07 a-d
ICV 10	38.28	53.89	52.99	48.38 ab
Yatta 2	34.68	43.09	44.49	40.75 a-d
TVu 1509	22.64	33.69	29.31	28.55 bcd
ICV 1	13.64	29.22	33.09	25.32 d
ICV 3	37.60	47.62	53.03	46.08 abc
ICV 6	31.83	45.49	50.99	42.77 a-d
ICV 2	19.94	27.29	29.71	25.35 cd
ICV 4	19.13	32.93	39.62	30.53 bcd
Nya'chula	46.08	63.25	60.88	56.74a
Pooled means	30.89 b	40.45 a	45.44 a	
C.V.	17.58%			
S.E.	3.00			

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vg: Average weight of seeds per pod

Cultivar	Protected	Unprotected	Control	Pooled means
Nya'milambo	1.20	1.29	1.41	1.30 d-g
Katumani 4	1.29	1.47	1.58	1.44 bcd
ICV 5	1.35	1.65	1.72	1.52 abc
Nya'mbita	1.64	1.66	1.87	1.72 ab
Ife brown	0.95	0.99	1.04	0.99 g
ICV 10	1.04	1.37	1.61	1.34 b-e
Yatta 2	1.37	1.43	1.47	1.42 c-f
TVu 1509	0.65	0.71	0.68	0.68 h
ICV 1	1.09	1.10	1.15	1.11 fg
ICV 3	1.81	1.84	2.05	1.90 a
ICV 6	1.14	1.21	1.13	1.16 efg
ICV 2	1.11	1.17	1.09	1.12 efg
ICV 4	1.03	1.18	1.21	1.14 efg
Nya'chula	1.63	1.77	1.84	1.74 ab
Pooled means	1.23 b	1.34 ab	1.42 a	
C.V.	4.45%			
S.E.	0.103			

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vh: Percentage of pods malformed per plant

Cultivar	Protected	Unprotected	Control	Pooled means
Nya'milambo	44.09	45.10	45.53	44.91 bc
Katumani 4	45.43	37.04	38.96	40.47 bc
ICV 5	48.12	38.78	40.58	42.49 bcd
Nya'mbita	31.41	32.99	33.72	32.71 d
Ife brown	67.12	63.76	59.05	63.31 a
Yatta 2	37.25	39.56	37.27	38.03 cd
ICV 10	37.10	41.93	38.91	39.31 bcd
TVu 1509	48.61	50.12	47.52	48.75 bc
ICV 1	50.73	54.16	47.705	50.86 bc
ICV 3	28.05	32.32	32.41	30.92 d
ICV 6	41.84	49.14	53.14	48.04 bc
ICV 2	51.84	44.37	52.33	49.51 bc
ICV 4	54.14	48.96	52.79	51.96 b
Nya'chula	25.35	31.64	35.89	30.96 d
Pooled means	43.65 a	43.56 a	43.97 a	
C.V.	9.97%			
S.E.	1.83			

Values followed by similar letters within columns are not significantly different at 5% level (Duncans multiple range test).

Appendix Vi: Percentage of pods with seeds per plant.

Cultivar	Protected	Unprotected	Control
Nya'milambo	96.4	98.4	97.6
Katumani 4	90.9	92.9	92.2
ICV 5	93.7	94.9	95.3
Nya'mbita	93.9	94.4	95.1
Ife-brown	94.9	92.7	95.6
ICV 10	93.9	93.4	96.5
Yatta 2	98.3	98.4	98.8
TVu 1509	95.1	95.9	96.8
ICV 1	94.4	97.4	96.3
ICV 3	97.5	97.8	97.7
ICV 6	97.4	97.5	95.6
ICV 2	97.7	96.9	96.1
ICV 4	96.2	96.3	96.3
Nya'chula	98.8	98.4	98.4
Pooled means	95.6	96.1	96.3
CV	5.12%		
S.E.	3.12		

No significant difference at 5% level.