Title: The Effect of Intercropping resistant and Susceptible cowpea cultivars with maize on the Infestation and damage by the legume pod borer Maruca testulalis Geyer and stem borer complex on maize.

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ABSTRACT.

Intercropping or mixed cropping is the most common agricultural system in developing countries. One of the most predominant combination involves grain legumes grown in association with cereals. This practice is characterized by a reduced pest population compared to monocrop. This reduced pest population in mixed cropping is due to a number of factors, some of which are physical, natural enemies, microclimatic gradient and chemical interactions. Some crops may act as dispersal barriers to migrating pests. The consequences the prevailing factors in a mixed cropping agro-ecosystem have on host plant resistance or susceptibility are not clear since most of the crops are selected and bred for use in monocultures.

In these present investagations, field and screen cage experiments were conducted to determine and quantify the effect of mixed cropping resistant and susceptible cowpea cultivars with maize on the incidence of legume pod borer *Maruca testulalis* Geyer and also monitor the effect of intercropping on the relative resistance and susceptibility of cowpea cultivars to *Maruca*. Colonization processes of *Maruca* on these varieties, environmental variables between cropping systems and the stem borer complex on maize were also observed. The studies were conducted at Mbita Point Field Station in South Nyanza district of Kenya for three

consecutive cropping seasons of 1987 and 1988.

Experimental design used in both field and sreen cage experiments was randomised complete block. However the data was analysed in split plot designed manner. This type of analysis was necessary so as to show the differences between the cropping systems and varieties.

Results obtained revealed that larval population of *M. testulalis* were significantly different according to the varieties, cropping systems and seasons. These differences were much more related to the intercropping than resistance or susceptibility. The subsquent larval population was actually the one that was affected by mixed cropping. However the number of larvae did not differ significantly ($p = 0.05$) when resistant cultivar TVU 946 was compared to the susceptible cultivar ICV2 when both cultivars were in pure stands.

Reduced sunlight reaching the cowpea canopy in the intercropped stands greatly reduced the number of pods/plant. This resulted in the reduction of the infestable pods and hence a reduction in the number of pods with larval damage. The incidence of *Maruca* larvae during the long rains was higher than during the short rain season. However as the number of larvae increased so was the number of pods and seeds with damage symptoms.

The population density and build up of *M. sjostedti* were significantly ($p = 0.05$) lower in the mixed crop during the short rains seasons than during the long rains. However resistance traits of cultivar TVU 946 did not have a significant effect on the population build up in the mixtures. The results revealed that reduced light intensity in the cowpea/maize mixtures contributed to the low number of the thrips.

Results indicated that intercropping affected the relative resistance and susceptibility of cowpea cultivars. The resistance of TVU 946 was reduced when the cultivar was planted together with maize. This could have been due to the phenological changes that were observed. When the variety was planted together wih maize, pods and peduncles were significantly longer while the branches were significantly fewer.. The changes were attributed to the micro-environmental conditions that were created by maize suggesting that cultivar TVU 946 is not well adapted to intercropping.

In the screen cages, stems of cultivar TVU 946 when interplanted with maize, were equally damaged as those of cultivar ICV2. Similarly for cultivar ICV2, intercropping reduced the amount of damage caused by *Maruca*. It was, therefore assumed that microclimatic differences created by intercropping had an adverse effect on resistance of TVU 946, since its resistance is rather phenologically oriented thus modifying it genetically.

There was a plant age preference for oviposition on the cowpea cultivars with the underlying role of intercropping being demonstrated by the fact that there were significantly ($P = 0.05$) more *Maruca* eggs in pure stands than in the intercrop. Similarly the role of resistance and susceptibility during the initial colonisation in the field was realized, with the resistant cultivar TVU 946 having fewer eggs than cultivar ICV2. The subsequent larval population was not affected by mixed cropping. In the screen cage more eggs were recorded on the edges of all the intercropped plots and on pure stands of all the two varieties.

Weekly mean temperatures and relative humidities indicated that there were significant ($p = 0.05$) differences between cropping patterns. Temperatures were lower and relative humidities higher in the intercrop. Similarly there was significant reduction in the photosynthetic active radiation incident on cowpea canopy in all the intercropped plots.

C. partellus was found to be the dominant stem borer within the study area and its populations were only slightly regulated by mixed cropping. However other borers namely *H. armigera* and *E. saccharina* were recorded later in the season on silk and top seed respectively.

Land equivalent ratios(LER) for the cropping seasons were significantly ($p = 0.05$) higher, indicating that intercropping had yield advantage with both cultivars. It is therefore concluded that intercropping maize and cowpea reduces pest damage on cowpea, however it is capable of modifying the level of resistance.

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INTRODUCTION

Current approaches to pest management involve the integration of several methods of pest control, which depend on several characteristics of an agro-ecosystem (Altieri et. al., 1978). One of the main characteristics is that of multiple cropping system which is commonly practiced traditional agricultural system in the tropics (Willey and Osiru, 1972; Perrin, 1977).

Multiple cropping in the tropics is an important component of small scale agriculture and depends on various factors namely climatic conditions, seasonal variations, agronomic practices ,labour availability and other social factors (Fransis et. al., 1975, 1977). The success of multiple cropping pattern on the diversity of the vegetation within the cropping area.

Multiple cropping, intercropping or mixed cropping are terms which have been used interchangeably to describe the planting of more than one crop in the same area in one year or season (Harwood, 1973). In this system two or more crops can be planted simultaneously within sufficient spartial proximity which results to interspecific competition and complementarity (Hart, 1974).

The advantages of intecropping as suggested by Willey(1979) are the greater yield stability over different seasons, higher yield in a given season, better use of resources such as optimisation of labour, area of land and minimization of risks against weather and price fluctuations (Finlay, 1975a; Nangju, 1975, 1976). It also reduces soil erosion and weed growth while maintaining soil fertility (Finlay, 1975b). A combination of several crops is also believed to provide nutritionaliy balanced food source over a long period of time (Juerez et. al., 1982). The most outstanding advantage in this respect is that intercropping system reduces insect damage by the principle of increasing the diversity of an agroecosystem (Kayumbo, 1976, Karel et. al., 1980; Lawani, 1982; Amoako-atta et. al.,1983; and Amoako-atta and Omolo, 1983). Greater yield stability is a very important aspect in small scale farms in that case if one crop fails or grows poorly, the other crop can compensate (Gomez and Gomez, 1983). However, crop combination, cropping pattern, location and the cropping season all contribute to the whole complex of results obtained from multiple cropping practices (Amoako-atta et. al., 1983; Amoako-Atta and Omolo, 1983; Osiru,1976; Osiru and Willey, 1972).

It has been realized that although intercropping is incompartible with modern methods of agriculture and its pest management strategies, ecological analysis of the insect pests which have yielded conflicting results is important. As regards pest damage, intercropping have certain distinct advatages over monocultures (Nangju, 1976). For example Kaufmann(1983) while studying the population dynamics of the maize stem borer in Nigeria found that the number of borers in the pure stand was slightly more than twice that of maize cassava intercrop. Juarez et. al (1982) later indicated that in an intercropped system pests of variuos crops and their natural enemies are brought together. Reduction of insect pests in an intercropped ecosystem has also been attributed to the confusing olfactory and visual clues received from the host and non-host plant which disrupts normal feeding and mating behaviour (Tahvanainen and Root, 1973; IRRI, 1973; Kayumbo, 1976; Saxena, 1985). Juarez et. al.(1982) contended that taller plants provided physical barriers which prevented some insects from penetrating the lower strata. However evidence from field experimentation has been conflicting. For example, it has been demonstrated that in some instances vegetational diversity occasionally has a positive effect on insect and their natural enemies (Way,1953, 1983). Meloid beetles and some sucking bugs(eg. *Clavigralla* spp.) have been found to be favoured by crop combination of maize intercropped with cowpeas. These insects oviposit on maize while feeding on cowpea indicating that maize enhances their movement from one host to another. Also increased shading, humidity and reduced temperatures favour higher populations of these foliage beetles (Matteson, 1982; Ochieng, 1977; Kayumbo, 1976). To the contrary, low insect build up has been found to be one of the many advantages of multiple cropping which is as a result of the increased complexity of plant species thus providing unfavourable habitat for insects (Gerard, 1976; Karel and Mueke, 1978; Kayumbo, 1976). But this situation mainly depends on crop component within the mixture, seasonal changes, location and cropping pattern (Omolo and Seshu Reddy, 1985). It should therefore not be assumed always that the diversity of agroecosystem is desirable for minimizing pest damage.

The magnitude and expression of resistance or susceptibility of a plant to insect and pathogens are influenced by environmental factors which include climate, edaphic and cultural factors of crop environment (Singh, 1980; Saxena, 1985). Laboratory experiments have shown that the host plant can greatly influence not only the amount of colonization but also natality and mortality (Van Emden and Way, 1979). Incidentally high resistance of the host plant to the arriving insect appears to be a delicate mechanism of selective value to the insect perhaps because it helps to minimize over-exploitation by the insect of its food plant (Way and Bank 1968).

Host plant resistance essentially is the innate quality of the plant that renders it unutilizable as food or shelter for insect pest either through antixenosis(non-preference), antibiosis or the ability of the plant to tolerate without loss in yield at the levels of the pest that would severely damage a susceptible plant (Painter, 1951). Any types of these resistance can be used as one of the principle tools in pest management. Furthermore it can be integrated with other cultural control methods(eg. intercropping) (Jackai and Singh, 1983) where cropping systems can be manipulated in accordance with the target pest (Perrin, 1977).

Identification for genotypes suitable for intercropping has not attracted the attention of agronomists, entomologists and plant breeders. The majority of selected genotypes are mainly bred for monocultures in developing countries while under traditional situations they are normally grown in association with other crops by resource poor farmers (Osiru, 1980). It should therefore be determined as to whether crop varieties selected as resistant or susceptible to insect pests for monocropping are likely to perform the same when grown in association with other crops(intercropping).

Cowpea (*Vigna unguiculata* L. Walp) is one of the major sources of protein for the majority of the people living in arid and semi arid areas where it supplements starch staples (Anon, 1978; Khamala, 1978; Singh and Van Emden, 1979). However, agricultural surveys have indicated that there is low production and availability of this grain legume (Raheja, 1977a). The main reason for this being that in a given area, farmers obtain very low yields at an average of 180Kgs/ha (Booker, 1965a). These low yields have been attributed to damage by insect (Booker, 1965a, Raheja, 1977b). Among the insect pests are the aphids, the pod borer(*Maruca testulalis* Geyer), flowerbud thrips(*Megalurothrips sjostedti* Trybom) and several species of coreid bugs. The legume pod borer *M. testulalis* and the flowerbud thrips *M. sjostedti*, are the most important insect pests causing yield losses of up to 80%. It is therefore recognized that in order to obtain any yields from sole crop of cowpea, pest control is essential (Singh, 1978b, Singh and Van Emden, 1979). At present, the use of insecticides is the only available control measure for major pests like *Maruca* (Karel, 1985) However they are not widely used (Singh et. al., 1978).

Attempts have been made to identify resistant cowpea cultivars to various cowpea pests and have been found to offer a promising alternative control method for pests like *M. testulalis* (Singh, 1977, Nangju, 1976). Some of the cowpea lines identified have moderate levels of resistance to *M. testulalis* (IITA, 1981; Jackai, 1982).

The legume pod borer *M. testulalis* is widely distributed in the tropics and subtropics (Singh and Allen, 1980) In Kenya results have indicated yield losses of between 10 and 80% when cowpea is planted as a sole crop (Okeyo- Owour and Ochieng, 1981). Oviposition occurs during the flowering period and upon hatching young larvae feed inside the flowers causing substantial damage (Taylor, 1978; Okeyo-Owuor and Ochieng, 1981; Raheja, 1977a). Usua and Singh (1978) also found this pest attacking stems causing substantial damage mostly on the susceptible cowpea cultivars.

Presently, application of insecticides is the only effective method for control of *Maruca* on cowpea if reasonable yields are to be obtained although as mentioned earlier there are lines which are moderately resistant to this pest (Singh, 1978b, 1984; Karel, 1985).

Another pest of cowpea which is also regarded as important is *M. sjostedti* commonly reffered to as flowerbud thrip (Moffs, 1983). Damage by this pest to cowpea as reported by Okwakpam (1977) is on flowers. But Singh(1977) reported that this pest caused more damage to young developing flowerbuds which turn brownish and abort due to feeding by nymphs and adults.

However, small scale farmers in nearly all cowpea growing areas never apply any insecticide in the control of these two pests since cowpea is never planted as a sole crop but intercropped with cereals such as maize and sorghum and other arable crops like cassava (Anon, 1978). Also the use of some insecticides does not favuor the immediate utilization of cowpea leaves as vegetables (Khamala, 1978). Some of these limitations facing the small scale farmer made it necessary for researchers to come up with non-chemical methods of pest control such as the use of resistant varieties (Kayumbo, 1976; Jackai, 1982).

The use of resistant cowpea cultivars as opposed to susceptible ones has successfully been used as one of the insect control methods (Painter, 1951, Jackai and Singh, 1983). Resistant cultivars are particularly advantageous in that, they reduce the usage of insecticides. They also help in reducing the development of pest resistance to insecticides and also do not pose any threat to parasites and predators, and hence no extra cost to the farmer (Singh, 1978b).

Most of the cowpea cultivars thought to be resistant or susceptible are selected for monocropping (Jackai and singh, 1983). However Saxena (1985) indicated that the expression of resistance in plants though genetically controlled may be affected by other factors such as insect response to particular stimuli, other organisms present and environmental factors (light, humidity and temperatures) which may at times determine the phenotype. It is important to obtain information on the role of intercropping on the resistance or susceptibility of cowpea cultivars.

In the tropics stem borers are considered as the most important pests of maize (Usua, 1968a). According to Hill (1975), the well known destructive example are found among Noctuidae ie. the maize borer *Busseola fusca* (Fuller), the pink stalk borer *Sesamia calamistis* (Hampson) and the puple stem borer *Sesamia inference* (Walker) while among the Pyralidae are the spotted stalk borer *Chilo partellus* (Swinhoe) and coastal stalk borer *Chilo orichalcociliellus* (Strand).

A survey conducted in Kenya on the stem borer complex of maize and sorghum by Anon (1981); Omolo and Seshu Reddy (1985) indicated that *C. partellus* and *C. orchalcociliellus* were the major stem borers in the lower altitude areas of the coast and the lake region, *B. fusca* being second in importance. *Eldana sacharina* is principally a pest of sugar cane but has spread to sorghum and maize. Sesamia spp. have a wide distribution in most lowland cereal growing ares of East Africa. The same survey also indicated that distribution of these stem borers were influenced by altitude, temperatures and rainfall patterns resulting to *Chilo* spp. being most important in warmer areas while *B. fusca* is dominant in cooler areas.

Detailed studies on intercropping maize, sorghum and cowpea by Amoako-Atta and Omolo(1983), Amoako-Atta et.al. (1983), Dissemond (1984), Omolo and Seshu Reddy (1985) have identified the cereal/legume (maize/cowpeas) as a good combination in terms of stem borer control. This combination forms a traditional intercropping system followed by most farmers.

Knowledge on the effect of resistant and susceptible cowpea cultivars on *Maruca* and thrips infestation when cowpea is intercropped with maize is scanty. The present studies were therefore undertaken with the following major objectives:

1. To study the effect of intercropping resistant and susceptible cowpea cultivars with maize on legume pod borer ***M. testulalis***.

2. To study the extent to which intercropping would influence the level of resistance and susceptibility of cowpea cultivars to *M. testulalis*.

3. To study the colonisation process to resistant and susceptible cowpea cultivars with emphasis on oviposition.

4. Study the microenvironment differences between the pure and intercropped cowpeas and the subsquent effect on the colonization of *M. testulalis*.

5. Study the stem borer complex and incidence on maize when intercropped with resistant and susceptible cowpea cultivars.

The objectives were achieved by testing the following hypothesis;

1. Intercropping affects the infestation of legume pod borer on resistant and susceptible cowpea cultivars.

2. Resistance and susceptibility of cowpea to *Maruca* is affected by intercropping.

3. Colonisation processes of *Maruca* on resistant and susceptible cultivars are interfered with by intercropping.

4. Microclimatic differences between pure and intercopped stands affect the colonisation process of *Maruca*.

5. Stem borer complex and incidence is affected by intercropping maize with resistant and susceptible cowpea cultivars.

CHAPTER 1

LITERATURE REVIEW

1.1. INTERCROPPING AND PEST MANAGEMENT

Intercropping or mixed cropping is the main feature of cropping system in the tropics, where two or more crops are grown simultaneously in the field (Anon, 1978 ; Perrin and Phillips, 1978). There are other types of intercroppings namely mixed cropping, where there is no distinct row arrangement, row intercropping where plants are grown in rows, strip intercropping with crops being grown in different strips wide enough to permit independent cultivation and the relay intercropping where two or more crops are grown simultaneously for a part of life cycle of each, and the second crop being planted before harvest of the first crop (Andrew, 1974; Perrin and Phillips, 1978).

Pimentel (1961) ; Southwood and Way (1970); Nickel (1973), Van Emden and Williams (1974) contended that although monocultures are highly productive than polycultures, they have a high genetic and horticultural uniformity which results to continous pest susceptibility.

According to Altieri et. al (1978), the terms polyculture, mixed cropping, double cropping and crop association have been used interchangeably to describe the planting of more than one crop in same area in one year. In designing and management of these cropping systems, one strategy is to minimize negative competition and maximize positive complementarity among species in the mixtures (Francis et. al., 1976). In the tropics intercropping has been an important component of small farm agriculture, and one reason for the evolution of this type of cropping system may be less incidence of pests and diseases (Francis et al 1976).

1.1.1 Advantages of Intercropping (mixed cropping).

In agriculture, experimental studies have clearly demonstrated that where labour is intensive and where pest and diseases are usually high, mixed cropping systems give a high and more dependable returns than in monoculture systems(Norman, 1974, 1976; Agboola and Fayemi, 1971; Finlay, 1975b; Nangju, 1975). Studies conducted in IRRI (1974) have shown that there is high productivity in terms of gross returns per hectare in terms of land equivalent ratio when soya beans were intercropped with maize. This increased productivity has been attributed by Parker(1969) and Norman (1976) to;

1. More efficient use of solar radiation due to better interception of light by the foliage per unit space .

2. Positive interaction between diffent plant species, for example the increased yields of cereals when mixed with legumes due to availability of nitrogen fixed by the legumes (Agboola and Fayemi 1971).

3. Efficient use of soil moisture and nutrients associated with different rooting depth of constituent crops (Suryatna and Harwood, 1976).

4. Improved soil by maintainance of fertility as well as preventing soil erosion and weed growth (Finlay, 1975a).

5. The potential compensatory growth of those crops in an intercrop which suffers least from vagaries of the environment (Fisher, 1975b).

6. Reduction in insect damage, by the principle of increasing the species diversity of an agroecosystem (Lawani, 1982).

1.1.2. Insect Pests under Intercropped Ecosystem.

In the tropics where crop pests cause serious damage,foresters and farmers have long since recognised that individuals of a species in pure culture are more heavily damaged than individuals of the species interspersed among individuals of other species (Trenbath, 1976). Intercropping as a cultural method of pest control is based on this principle of increasing diversity of an agroecosystem and its effect on the population dynamics of the pest (Way, 1977 ; Perrin and Phillips, 1978 ; Lawani, 1982).

TrenBarth (1976), Perrin (1977) and Perrin and Phillips (1978) contend that the main process by which pest problems are reduced in mixed culture is influenced by various factors such as;

(a) Colonisation of crops.

According to Tahvainainen and Root(1973), interplanting non-host plants can drastically decrease colonization efficiency and subsquent population density which according to Perrin (1977) is caused by;

(i) Visual effects:- A mixture of crop types may affect the visual distant perceivable stimuli that attracts insect pests to their suitable host plants where in some cases, one crop becomes totally comouflaged by another from flying insects. Cromartie(1975) found that the vegetational background of a collard crop, *Brassica oleracea* had different effects on fauna associated with it. He also found that plot size produced significant effects on insect colonisation. *P. rapae* successfully invaded single plant stands, whereas *Phyllotreta cruciferae* prefered the 100 plant stands.

(ii) Olfactory effects:- Host plant orientation in insects involves olfactory mechanisms (IRRI, 1973; Nangju, 1976; Perrin, 1977; Saxena, 1985). Studies conducted at IRRI (1973) on feeding and searching behaviour indicated that cabbage, which is a natural host of diamond back moth *Plutella xylostella* L., when interplanted with tomatoes, a non-host, had fewer eggs and adults than cabbage in pure stands. However, there are other cases where polyphagous insects may be attracted by mixed odours as with the case of the coreid bugs *Clavigralla* Spp. which is attracted to other legumes when they are interplanted with pigeon peas (Kayumbo, 1976).

(iii) Diversionary hosts:- Some crops are planted as trap crops where they act as diversionary hosts by protecting other more susceptible or economically valuable crops from damage (Perrin, 1977). Raheja(1973) found that unsprayed cowpea is less subjected to insect damage when intercropped with sorghum rather than in sole crop indicating that some polyphagous pests prefer cereals. An edge effect of *Ootheca* sp. population have been observed when cowpea was intercropped with maize. Here the migrating adults initialy colonise the outer rows with the maize restricting their subsquent dispersal(Kayumbo, 1976). Way (1975) reported that *Crotalaria SPP.* sown prior to cowpea helped to protect cowpea from legume pod borer_*M. testulalis*.

(b) Pest population development:-

The confusing visual and olfactory stimuli received from host and non-host plants may disrupt normal feeding or mating behaviour of an insect (Tahvananainen and Roots, 1973). Similarly, the reduced tillage and smaller size of individual plants when intercropped has been considered to decrease disease incidence (Wilhelm, 1973). However in some cases, more favourable habitats for pests is created when a pest is allowed to switch from a senescing to a more suitably younger crop and continues to increase in numbers (Kayumbo, 1976). According to Perrin (1977), rapid population build up is naturally favoured where pests find their food, shelter and oviposition requirement within the crop. However, the benefits of multiple cropping may depend on how pest populations are affected at critical developmental stages in crop growth.

(c) Dispersal:-

Because many pests and disease organisms tend to be specialized to attack just one or a small group of host species,the individuals of other plant species (non-host) in a mixture constitute a pontentially absorptive barrier to movement between those plants which can be attacked (a "fly paper effect") (Trenbath, 1976; Perrin, 1977). This concept has been observed by Taylor(1977) that less flower damage due to *M. testulalis* occurred when cowpea was intra-row rather than interrow cropped with maize. A similar observation is reported by Gethi and Khaemba (1985) who observed that the outer cowpea rows when intercropped with maize, harboured more *M. testulalis* larvae than the center of the plots. Gethi(1986) also observed this kind of behaviour on cowpea flowerbud thrips (*M. sjostedti*). Kayumbo et. al. (1976) observed more cluster distribution of *O. bennigseni* and coreid bugs on mixed rather than mono-cropped cowpea, and attributed it to restricted movement of adults between plants. Amoako-Atta et.al. (1983) also observed that differences in relative abundance of *M. testulalis* to the cowpea when intercropped with maize or sorghum

could have been due to the fact that pest migration could have been impaired by the non host plant which acted as physical barriers to inter- or intrarow migration. Therefore, barrier hazards to insect dispersal should be regarded as a bases of insect pest control as was suggested by Way(1975).

(d)Predators and parasites abundance:-

One of the hypothesis used to explain low insect population in a complex environment (eg intercropping) is that predators and parasites are more effective in this kind of situation (Roots, 1973 ; Altieri et al, 1978). However Perrin (1977) stated that natural enemy abundance may be decreased by multiple cropping, particularly if they respond to the confusing visual and olfactory cues. Studies at IRRI (1973,1974) and Raros (1973) showed that intercropping maize and groundnuts greatly reduced the damage to maize by the corn borer *Ostrinia furnacalis* Gn. They attributed this reduction to the increased activities of predatory wolf spiders (*Lycosa* spp.).

Altieri et al., (1978) working on leaf hoppers (*Empoasca kraemeri* Ross.) showed that there were signifantly fewer adult leaf hoppers on beans in the maize/bean polyculture compared to monoculture beans. These authors contended that the reduction was not due to diversity in cropping system but due to egg prasitoid (*Anagyrus* sp) of *E. kraemeri* which showed higher activity in polycultures.

(e) Associational resistance :-

Restricted dispersal of insect pests may also result from mixing resistant and susceptible cultivars of one crop (Van Emden, 1976). Baker and Cook (1974) had earlier suggested the idea of cultivating cereals as multiline mixtures in order to stabilise their associated biological communities. Extensive work on multiline mixtures and it success in reducing stem borers in sorghum has beeen reported by Omolo et. al (1990) .

(f) Micro-environmental effects:-

The presence of a companion plant in an intercropped system creates a micro-environment for the susceptible crop which differs from that found in pure culture (Trenbath, 1976). These micro-environmental differences are thought to affect host-parasite relationship by either influencing the population of natural enemies attacking the organism, or by acting on the potentially attacked component changing its susceptibility or act directly on the attacking organism (Trenbath, 1976). For example where cowpea is grown under maize, the lower temperatures and higher relative humidity are unfavourable to the colonisation by flowerbud thrips (Anon, 1985). Similarly, in the Phillipines, the corn stalk borer was found to be less abundant in maize/ ground nut mixtures because spiders which prey on them were favoured by the environment in the mixtures than in pure maize (IRRI, 1973, 1974).

Willey and Osiru (1972) and Gardiner and Craker (1981) found that when maize was intercropped with beans, there was a reduction of the photosynthetic active radiation incident on the bean canopies which resulted to reduced number of leaves and pods and hence affected the feeding sites of certain pests.

The effect of cropping patterns on the population dynamics of pests can be summarised as in figure 1.1 from Perrin (1977).

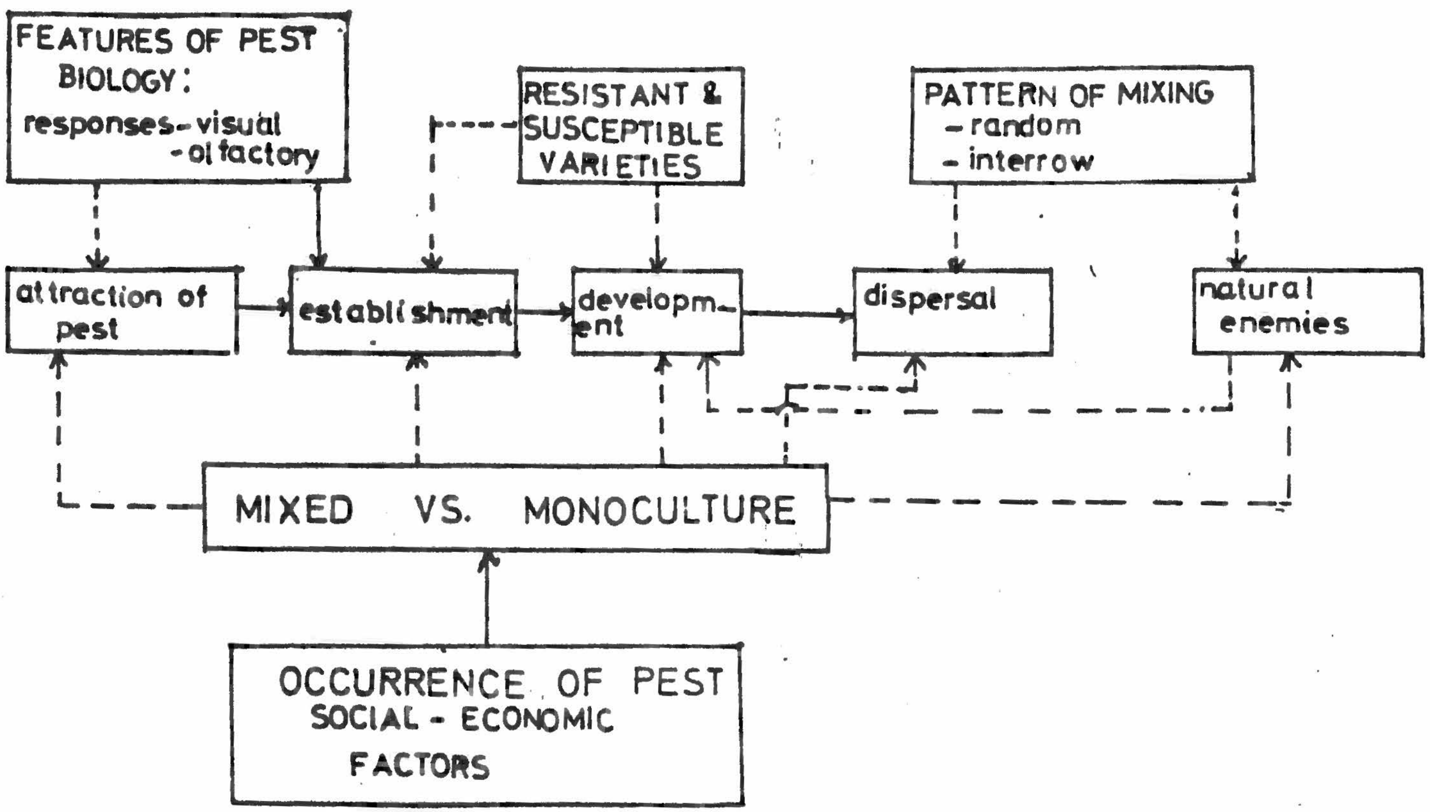
Altieri et. al., (1978) suggested that although pest regulation mechanisms mentioned above are not fully understood, some factors which condition a lower pest incidence in mixed cropping are more of natural enemies, microclimatic gradients (mainly shading) and chemical interaction. He also suggested that these factors function together as an associational resistance.

1.2. Pests of cowpea:

The cowpea (*Vigna unguiculata* L. Walp.) is one of the major crops in arid and semi-arid areas in Africa where it forms a variable source of protein (Booker, 1965). In drier parts of East Africa, cowpea green tender leaves are used as a "spinach" crop, the immature pods as a vegetable, and the seeds as a pulses (Koehler and Mehta, 1972).

Earlier Sellschope (1962) considered cowpea to be

Figure 1. 1 Schematic diagram showing the features of pest population that are affected by intercropping



among the most important leguminous crops in Africa, taking third position to groundnuts (*Arachis hypongea* L.). In Kenya about 67000 ha. were under cowpea in 1977 out of which a total of 62,000 ha. consisted of cowpea grown extensively in mixtures with other crops (Anon, 1978). About 85% of cowpea is grown in the marginal rainfall areas of Eastern province while 8% is produced in Coast province and the rest in Nyanza and Western provinces (Khaemba, 1980).

Cowpea yields in Kenya have ranged from 150 to 500 Kg/ha.,which is extremely low in view of the fact that yields as high as 1500Kg/ha. can be obtained by protecting the crop from pest attack (Khaemba, 1978; Khaemba, 1980). The primary cause of such low yields is the damage done by insect pests (Booker, 1965a). Almost every part of cowpea plant is attacked by one insect species or another (Koehler and Mehta, 1972). Earlier Booker (1965b) working in Nigeria listed as many as 85 species that cause injury to cowpeas of which only a few of them were considered to be major pests.

Major pests of cowpea can be divided into two groups,namely pre-flowering and post-flowering of which the latter are the most important (Booker, 1965a). According to Singh and Van Emden(1979), the pre-flowering pests include *Ootheca* spp which are leaf eating beetles, *Alcidodes leucogrammus* (Erichs), a stem girdler of which both larvae and adults cause damage and leafhoppers mainly in the genus *Empoasca* with *E. dolichi* being the main species found in Kenya. Also among the pre-flowering pests are aphids such as *Aphis craccivora* (Koch) and bean flies in the genus *Ophiomia* . A large number of bettles feed on cowpea although they are of minor importance.

Post-flowering pests of cowpea are the most important. These pests include the flowerbud thrips *M. sjostedti* which feed on flowerbuds and flowers causing severe damage. *M. testulalis* or the legume pod borer is the major pest of cowpea attacking both vegetative and reproductive parts of cowpea crop (Okeyo-owuor et. al., 1983). Other post-flowering pests of major economic importance are coreid bugs which includes the *Nezara viridula, Anoplocnemis curvipes* (F.), *Riptortus* spp mainly *R. dentipes* and *Clavigralla* spp. These bugs feed on green pods causing pre-mature drying and shrivelling. The shrivelled pods produce no seed (Singh, 1979). In storage, cowpea seed is attacked by two species of bruchids namely *Callosobruchus maculatus* Fab. and

Bruchidius atrolineatus Pic. (Raheja, 1977a). *Cydia ptychora*(cowpea seed moth) feed on the seed while still in the pod.

1.2.1. The Legume Pod Borer(*M. testulalis*).

1.2.1.1. Distribution, biology and control

The legume pod borer *Maruca testulalis* (Geyer) (Pyralidae, Lepidoptera) is one of the most important pest which limits production of cowpea crop in the tropical world (Taylor, 1978; Singh and Allen 1980). Singh and Van Emden(1979) reviewed its literature on distribution, damage, life cycle and control. As cited by these authors this pest is reported in East, West and South Africa(Booker, 1965; Halteren, 1978; Nyiira, 1973; Singh, 1977). In Asia, it is important in the Phillipines and India (Barroga, 1969; Saxena, 1974; Srivastava, 1964) and Papua New Guinea(Lamb, 1978). In South America it has been reported in Puerto Rico and in Brazil, while in North America it has been reported in southern areas.(Passlow, 1968).

The biology of this pest has been studied extensively by Taylor (1967) and Okeyo-Owuor and Ochieng (1981). Adult moths have dark greyish with white and brown patterned wings and they rest with their wings spread horizonitaly and when on cowpea crop they tend to rest under the canopy especially on the lower surface (Okeyo-Owuor and Ochieng, 1981). The female moths lay eggs on the flowerbuds, flowers and tender leaves and in captivity the moths oviposits liberally all over the host plant even on walls of cages(Singh, 1979; Taylor, 1978; Jackai, 1981). Oviposition takes place at night with the leaves being more preferred(Okeyo-Owuor and Ochieng, 1981). Eggs are usually laid in small batches with 10 - 100 eggs per female(Taylor, 1977). The eggs hatch in two to three days and the emerging larvae undergo five larval instars in 8 - 14 days (Taylor, 1967; Okeyo-Owour and Ochieng, 1981; Jackai, 1981; Singh and Jackai, 1985). There is a pre-pupal period lasting for 1-2 days during which time larvae do not feed. The pupal stage lasts for 5 - 15 days, with the whole life cycle lasting about 18 - 25 days depending on climatic conditions(Taylor, 1967; Okeyo-Owour and Ochieng, 1981).

The most serious damage is done by larvae to flowerbuds, flowers and green pods(Singh and Van Emden, 1979; Singh and Allen, 1980). The early generation can also attack peduncles and tender parts of the stem. The characteristic larval feeding symptoms is webbing together of flowers, pods and leaves with frass on the pods and shoots (Singh and Van Emden 1979).

The best control of this pest so far has been obtained with insecticides of which several are effective(Singh, 1977). Cowpea varieties resistant to attack by this pest have been indentified (Singh, 1977). Earlier Raheja (1973) had reported that attack by this pest is reduced when unsprayed cowpea is grown with sorghum, than when it is grown as unsprayed sole crop.

Maruca larvae in the field are attacked by very few natural enemies. Only a few hymenopteran and dipteran parasites have been identified from the field collected larvae. Among the hymenopterans are the Braconidae of the genus *Braunsia* spp and *Phanerotoma* species which attack larvae(Taylor, 1967). Usua(1975) also recorded another parasite of the genus Eulophipae(*Tetrastichus* spp) which also attacked larvae. Among the dipterans are the Tachinidae flies, *Thelairosoma palposum* which are also larval parasites(Usua, 1975). In addition to the above, *Maruca* larvae may be attacked by different species of predatorial insects like ants the most common one being *Camponotus species* which attacks larvae. Other predators identified are in the genus Aranae (spiders), namely *Selonops species* which feeds on both larvae and adults and those from the family Mantidae such *Polypilota species* and *Spodromantis species* both attacking the adults(Usua, 1975).

M.testulalis is known to have other host plants where it thrives very well. Taylor,(1978) listed a number of host plants identified from five plant families namely Papilionacea, Caesalpinacea, Pedalicea, Malvacea and Minosacea. However, the majority of these host plants belong to the family Papilionacea viz. *V. unguiculata, V. mungo, V. radiata, Cajanus* spp., *Crotalaria Spp., Arachis hypogea* (L), *Phaseolus vulgaris* (L) and many other plants in this family.

Jackai and Singh (1981) studied the suitability of flowers of eight different plant species of *Crotalaria* spp and *Vigna* species and found that there was a variability in the suitability of these plants as hosts of *Maruca*. Their results indicated that *V. unguiculata* was the most suitable host plant.

The flowerbud thrip is also regarded as a major pest of cowpea in all areas where cowpea is grown in Africa (Taylor, 1974; Khaemba, 1978). This pest attacks flowerbuds and flowers causing abortion and hence reduction in yields (Taylor, 1964, 1969, 1971; Singh, 1978a, 1979). Singh and Allen (1980) described the injury as being distortion and malformation of flowers in heavily infested plants. Studies on the population dynamics of the flowerbud thrips in Nigeria and Kenya indicated that the peak number of thrips was usually attained 12 to 34 days after onset of flowering (Taylor, 1969). According to Taylor (1974) seasonal abundance and population changes are never affected by temperatures and rainfall, but rather by flowering cycles and pollen abundance in the flowers. Eggs of the flowerbud thrips are laid in the flowerbud and upon hutching nymphs feed extensively on floral tissues. The entire life cycle takes 14 - 18 days(Singh and Allen, 1980). Anon(1984, 1985) indicated that population density of *M. sjostedti* on cowpea plants were significantly lower in cowpea/maize mixture compared to the sole crop of cowpea. He further suggested that shading resulting from maize plants significantly contributed to the reduction of thrips in the mixtures

1.2.1.2. Cowpea resistance to *M. testulalis*.

According to Herzog and Funderburk (1985), the primary objective of programms on resistance in crop plants is to develop crop varieties that are resistant to one or more insect pests while maintaining or improving agronomic characteristics,mainly yield. Painter (1951) proposed the following categorization of the mechanisms of plant resistance to insect;

a. Antixenosis:- This is a non-preference response of insect to plants that lack certain characteristics that allow them to serve as hosts which results from a choice on the part of individual while in search of food or oviposition substrate.

b. Antibiosis:- These are adverse effects of a plant on insect survival, development or reproduction.

c. Tolerance:- This is where the plant has the ability to withstand infestation and to support population that would severely damage susceptible plants. Painter (1951) further proposed another term, pseudoresistance to include apparent resistance which results from the expression of transitory characteristic of potentially susceptible hosts, which includes host evasion, induced resistance and escape. These mechanisms of resistance are important in host plant resistance, and can be used as a principle tool for pest control in certain cases. For instance, the control of aphids and leafhoopers can be achieved by use of resistant cowpea varieties (Singh 1980). Cultural pest control methods such as intercropping can be integrated with host plant resistance in controlling insect pests (Jackai and Singh, 1983). For example, cropping systems can be modified to include crop hosts that provide excellent habitat for beneficial insect populations (Herzog and Funderburk, 1985).

The economic impact of chemical control in cowpea production is indisputable (Singh and Van Emden, 1979). Chemical usage in the control of cowpea pest by the small scale farmer is still limited. According to Jackai and Singh (1983), this could be either because the farmers lack the technical knowhow or becausc the component of this technology(insecticides, sprayers etc) is not within their reach. It is therefore neccesary that other control options be investigated,but rather as a part of an integrated pest management programm for cowpea insect pests. If varieties resistant to insect pests are identified and developed, the use of chemical insecticides would be reduced(Nilakhe and Chalfant, 1982).

However, Singh (1977) and Nangju (1979) have published a lot of work on varietal resistance on cowpea in Africa. By 1983 the cowpea germplasm collection had reached 11,500 accessions (Singh, 1983) and from this a total of 6000 lines have been screened and identified as sources of different levels of resistance to *Maruca* (Singh et. al., 1984). TVU 946 was found to be the only cultivar having a certain degree of resistance and has been used as a donor of resistance in breeding programs (Singh, 1978b; Jackai, 1982; Dabrowski et. al., 1983; Singh et. al., 1984).

Several other cultivars have been reported to be moderately resistant. These include varieties like Vita 5 (Singh, 1978b; Jackai, 1982), Kamboinse local and TVU 1 (Jackai, 1982). Earlier, Singh, (1977) had reported that resistance of Vita 5 was due to long peduncles and its ability to escape damage. He also found TVU 3962 to be resistant to *Maruca* while Vita 4 was moderately resistant.

Singh (1978b), Jackai (1981, 1982) and Dabrowiski et. al. (1983) showed that flowers and pods of TVU 946 are significantly less damaged compared to other varieties and can escape damage by *M. testulalis* under natural conditions. Several sources of resistance in cowpea have been identified by Singh (1979) and Raman et. al. (1978). These authors showed that the mechanism of resistance in some cowpea varieties against leafhooper damage was due to antibiosis, and that resistance by cowpea variety TVX 3236 was due to non - preference and antibiosis. The major source of resistance in TVU 946 is due to its ability to mature early thus showing significantly lower levels of infestation and damage (Jackai, 1981, 1982). Singh (1979) attributed this resistance mechanism by TVU 946 to non-preference for oviposition, and antibiosis. Earlier Singh (1978a) had reported that narrow angle between two pods or pods touching each other enables a signinificantly higher infestation to occur (viz those varieties with pods touching each other are more susceptible to *Maruca* attack). Also the varieties that have short peduncles with pods inside the canopy such as ICV 2 are more susceptible to *Maruca*. This leads to a conclusion that plant characteristics enhance susceptibility to pod damage. Jackai (1982) and Dabrowski et. al. (1983), therefore concluded that plant architecture of TVU 946 is one of the factors responsible for less damage by M. testulalis.

1.3. Stem Borer Complex in an intercropped agro-ecosystem:

Maize is the most important food crop in Kenya and one of the most important cereals in the world (Kuria unpublished), unlike wheat and rice which are limited in distribution by climate.

Many insect pests attack maize in the field and in store where all stages of growth are vulnerable to several insect pests (Hill, 1975). Seedlings are attacked by cutworms, the germinating seed by weevils such as *Nematocerus* sp. which attack tender leaves, and occasionally by aphids(*Aphis maidis* Fitch) which feed on young leaves.

Stem borers are considered to be the most important pests of all graminaceous crops in the world(Jepson, 1954; Hill, 1975). These borers constitute one of the major constraints to efficient maize production in the developing world, where maize is considered as one of the most important subsistence crops (Scheltes, 1978). In the tropics more than 23 species of stem borers have been recorded (Nye, 1960; Seshu Reddy, and Davies, 1979) on both maize and sorghum. These borers cause damage by feeding on the leaves, in the whorls of plants and then bore inside the stems causing "dead hearts" on maize and chaffy heads on sorghum (Hill, 1975). In the tropics the stem borers known to be most destructive are found among the Noctuidae like the maize bore *B. fusca*, the pink stalk borer *S. calamistis* and the purple stem borer *S. inference* and among the Pyrallidae, are the spotted stalk borer *C. partellus*, coastal stalk borer *C. orichalcociliellus* and the sugar cane borer *E. saccharina* (Hill, 1975; Scheltes, 1978).

Studies conducted by Seshu Reddy(1983) showed that the stem borers *C. partellus*, *C. orichalcociliellus*, *B. fusca*, *S. calamistis* and *E. saccharina* were the most important borers of maize and sorghum in Kenya. Earlier studies by Anon (1980, 1981) on stem borer complex showed that *C. partellus* contributed to 90% of all borer species infesting maize and sorghum in lowland areas of Kenya. Anon (1981) and Seshu Reddy (1983) further reported that the distribution of stem borer species is influenced by the altitude, rainfall and temperature. In warmer and lower altitude areas, *C. partellus* was the most important stem borer. Earlier Ingram (1958) had reported that *C. partellus* could not live above 1500m. while *B. fusca* was found to be the dominant stem borer species in the cooler and higher altitude areas above 1500m. *S. calamistis* has been recorded at all altitudes from the sea level to 2600 m. and is common in hilly and irrigated areas (Seshu Reddy, 1983). Ingram (1958) had indicated that *E. saccharina* was not a pest of any importance in East Africa but Girling (1978) found this pest in maize, sorghum and sugarcane. Seshu Reddy (1983) also found *E. saccharina* on sorghum and maize mostly in the sugar belts of Western and Nyanza provinces of Kenya, and commented that this pest appeared to have widened its distribution since Nye's (1960) survey.

Several stalk borer control methods have been utilized, but the typical control method is by use of chemical insecticides (Warui and Kuria, 1983). This method according to Lawani (1982) is not applicable under peasant farmer situations due to the feeding behaviour of the borers. He indicated that once the larva has bored into the stem it is protected from the insecticide. The insecticide is supposed to be applied before the downward migration of the larvae. In order to obtain an effective chemical control of the stem borer, it calls for a precise placement of the chemical and careful timing (Lawani, 1982). Cultural practices which have been identified to reduce stem borer population includes sanitation, tillage, time of planting, spacing, rotation, use of fertilizers, mulching and irrigation (Bowden, 1976; Lal, 1979; Kaufmann, 1983). Host plant resistance has also been shown to offer an economical, stable and ecologically sound approach to reducing stalk borer damage (Ampofo, 1986).

Intercropping which is one of the cultural methods of pest control is based on the principle of increasing the diversity of an agro-ecosystem (Smith, 1970). In this kind of a system, attractive host plants may concentrate insect pests by diverting them from the other crops and making them vulnerable to predators and parasites. Results on the influence of maize when intercropped with other crops on the stem borer infestation have been reported by various authors(IRRI, 1973, 1974; Sastrawinata, 1976; Kaufmann, 1983; Amoako Atta et. al., 1983 and Amoako Atta and Omolo, 1983). Studies in IRRI (1974) showed that intercropping maize with groundnuts reduced the damage to maize by the corn borer *Ostrinia furnacalis* Gn. Sastrawinata(1976) intercropped maize with soya beans and groundnuts and found that intercropped maize had significantly lower numbers of egg masses, larvae, pupae and pupal cases of the corn borer *O. furnacalis* when compared with maize as a sole crop. The data on the population dynamics of *E. saccharina, S. calamistis* and *B. fusca* in maize when in pure stand and when intercropped with cassava indicated that there was a reduction in the number of borers in the intercropped stands than when maize was in pure stands (Kaufmann, 1983). Investigations by Anon (1986) also indicated that certain host/non-host combinations such as sorghum/cowpea, and cowpea/maize, reduced the borer attacks, whereas other combinations such as sorghum/maize enhanced pest attack. These studies suggests that intercropping has some potential as a cultural method of controlling some cereal borers and also there is likelyhood of the use of resistant/susceptible cultivars in intercropping as a way of pest management (Anon., 1984).

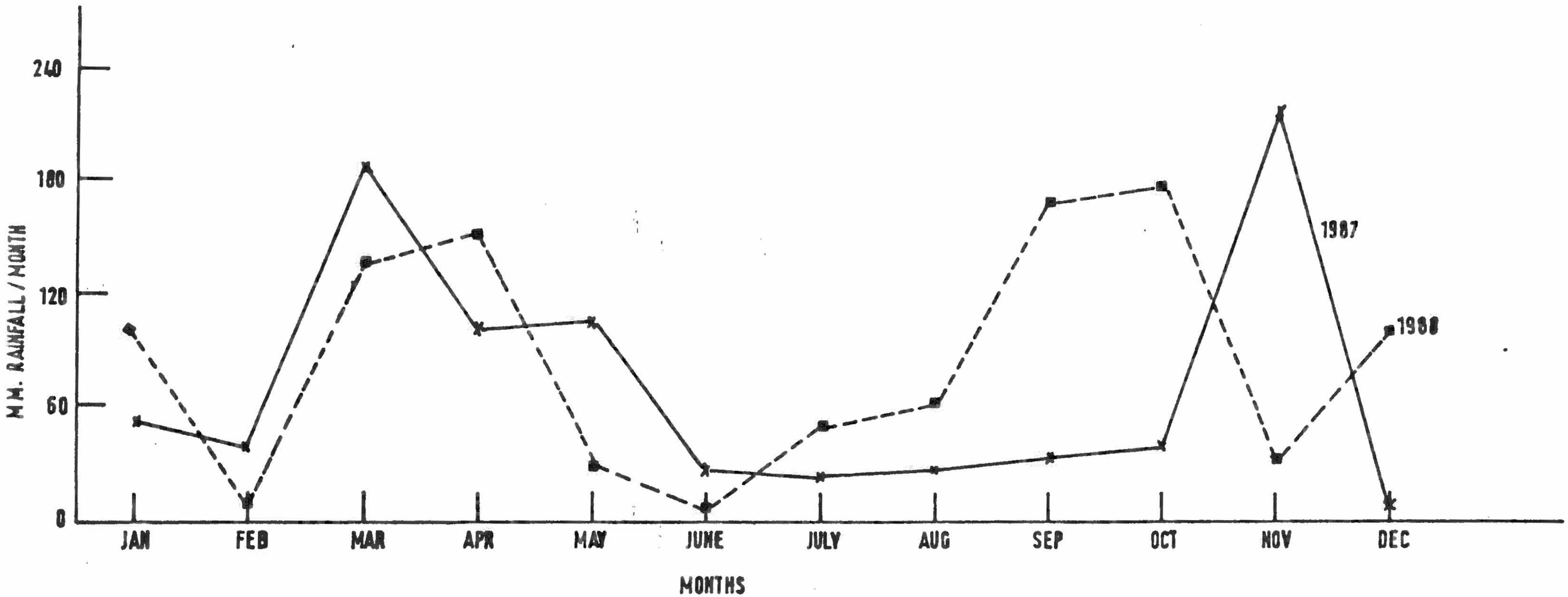
CHAPTER 2

GENERAL MATERIALS AND METHODS

2.1 Experimental Site.

The experiments reported here were carried out during the short rain of 1987, long and short rains seasons of 1988 at the International Centre of Insect Physiology and Ecology(ICIPE) Mbita Point Field Station. The centre is at the shores of Lake Victoria in South Western Kenya. The station is at an altitude of 1170 m. above sea level and has two rainy seasons; long rains which lasts from March to June and short rains in Octomber to November. The amount of rainfall varies from year to year and season to season. The rainfall pattern during the study period is shown in figure 2.1. Due to the unreliability of the rainfall during the short rains of the study period, irrigation was used. Temperatures during the long rains ranged from 21 to 30C while in the dry seasons, temperatures rose up to 35'C.

Figure 2. 1. Annual rainfall pattern for year 1987/1988 for Mbita Point Field station.



2.2. Crop Establishment:

Two selected cowpea cultivars, TVU 946 and ICV 2 were used for the study. TVU 946 is known to be resistant to *M. testulalis* due to its early flowering nature (Singh, 1978a) and thus escapes damage to flowers and pods. The cultivar has a maturation period of about 50 - 60 days. This cultivar is closer to the wild type cowpea, with very small pods which contain small black seeds which dehiscence at maturity. On the other hand, ICV2 is an early maturing cultivar with a maturation period similar to that of TVU 946, but susceptible to *Maruca*. It has a spreading, indeterminate growth habit (Pathak and Olela, 1986). The two cultivars are well adapted to semi-arid areas with erratic short duration rainy seasons.

The two cowpea cultivars were interplanted with Katumani composite: a maize cultivar which is relatively early maturing and drought escaping with a maturity period of between 90 -100 days.

The experiments were carried out using the additive model of intercropping. cowpea being the main crop and a certain proportion of maize added, thus ensuring that plant population of cowpea in both intercropped and pure stands remains constant (Osiru and Willey, 1972; Amoako Atta and Omolo, 1983)

After land preparation of the experimental site, the field was demarcated into twenty plots of 12m by 11.25m with 1m path way between adjacent plots. In the intercropped plots, maize rows were placed between cowpea rows. Both cowpea and maize were planted at the same time at the rate of 2 seeds per hole which was later thinned to one plant per hole at approximately two weeks after germination.

2.3. Design.

The design used in the experiment was Completely Randomised Block Design with five treatments being:

1. TVU 946 pure stand.

2. TVU 946 intercropped with maize.

3. ICV 2 pure stand.

4. ICV 2 intercropped with maize.

5. Maize pure stand.

Treatments were replicated four or three times depending on land availability with pure stands as controls.

Cowpea monocrop and in the intercrop had approximately 88,888 plants/ha at a spacing of 75cm X 15 cm. while maize monocrop and intercrop had approximately 44,444 plants/ha at a spacing of 75cm by 30 cm. No pesticides were used during the study period, and the plots were kept weed free throughout the study period by hand weeding .

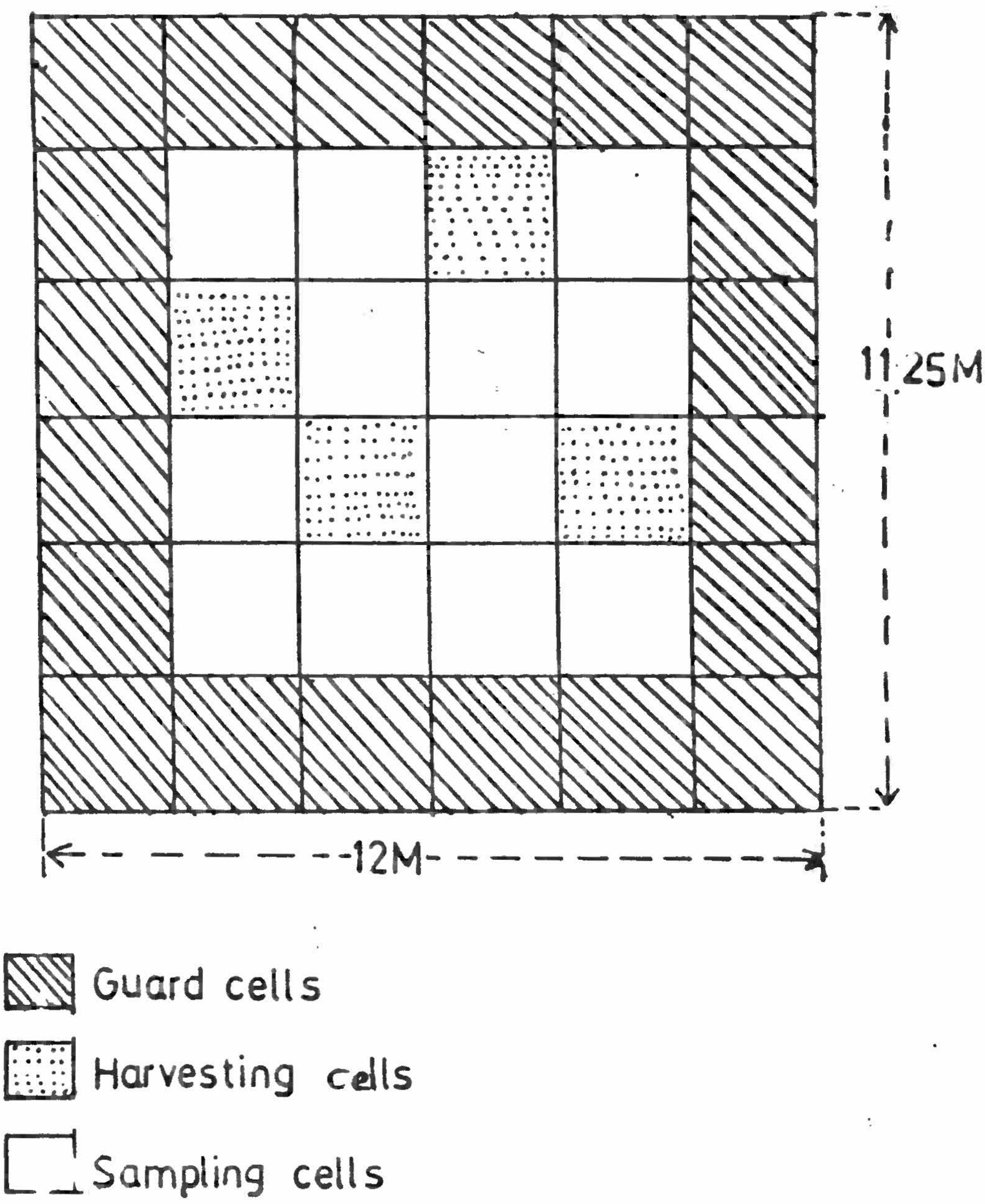
2.4 Sampling Procedure.

Each respective plot was subdivided into 36 equal cells measuring 2m by 1.875m using a pegged manilla string (Fig 2.2). The cells bordering the edges of the plots were considered as guard cells and were not included in the sampling or harvesting to avoid edge effect. Four of the remaining 16 cells were randomly selected and marked as harvesting cells and were therefore not interfered with during the season (Fig. 2.2). For each plot one cell was sampled once a week for eggs, nymphs, larvae and pupae without going back to it again.

2.4.1 Data analysis.

The data obtained from cowpea was analysed in

Figure 2. 2. Plot layout showing the sampling and harvesting cells in the cowpea and cowpea/maize intercropping studies.



accordance with split plot design taking cropping system as the main plots and varieties as subplots. The significance between the means were determined by F test after analysis of variance. Other statistical tests used for certain specific experiments are stated in the subsquent sections. However data for pest counts was transformed using square root x + 1 or log x + 1 transformation to standardize the variance before being subjected to analysis of variance.

CHAPTER 3

ESTIMATION OF THE EFFECT OF INTERCROPPING RESISTANT AND SUSCEPTIBLE COWPEA CULTIVARS WITH MAIZE ON *M.testulalis* POPULATION.

3 . 1 Introduction

Low build up of insect pest population is believed to be one of the many advantages realised from intercropping due to provision of a less favourable habitat for some of the insect pests than when crops are grown in pure stands (Nangju, 1976). Mixtures also prevent the spread of some pests to other areas due to the creation of physical barriers by the taller plants (Juarez et. al., 1982). Some studies on insect populations build up in mixtures have been reported by other workers (IRRI, 1974; Kayumbo, 1976; Gerard, 1976; Karel and Mueke 1978 and Gethi and Khaemba, 1985). However evidences from field experimentations have yielded conflicting results as regards to the above suggestions. Some reports have indicated that vegetational diversity has positive effects on some insects and their natural enemies (Way, 1953, 1983), while to the contrary, low insect build up has been recorded in mixtures (Gerard, 1976; Kaufman, 1983; Karel et. al., 1980). But there is very little experimental evidence on pest status under intercropping when combined with host plant resistance.

It was therefore considered appropriate to estimate the effect of intercropping maize with resistant and susceptible cowpea cultivars on the population build up of legume pod borer *M. testulalis*. The experiment was also expected to provide information on the infestation of *Maruca* on cowpea when intercropped and when in pure stand.

3 . 2 Materials and Methods

Infestation and damage by *Maruca* larvae was estimated by taking larval counts on the cowpea crop. Counting started from the 4th week after planting (approximately 25 days after planting) which also coincided with the onset of flowering. Sampling was done at 4 days interval for 4 to 5 weeks depending on the season at the end of which the crop was ready for harvesting. All the flowerbuds, flowers and pods, depending on the stage of the crop, were picked from a single row/sampling cell. Flowerbuds and flowers were put in petri dishes while the pods were put in polythene bags. They were then taken to the laboratory, dissected and counts of *Maruca* recorded.

At crop maturity all the pods from the harvesting cells (Fig. 2) where no sampling had been done were harvested for assessment of damage caused by the larvae (entry/exit holes). These pods were later sun dried and later threshed to determine the level of larval damage to the grains by recording the difference between the weight of the damaged and undamaged grains/plant.

Counts of the flowerbud thrips were also taken from the same set of flowers that were used for counting *Maruca* larvae. The sampled flowerbuds and flowers were dissected and washed in water twice to ensure maximum recovery of the thrips. This technique of extracting thrips from flowers is described by Ota (1968). Thrips which were freed in water and those still attached to floral parts were counted under the binocular microscope (X 12).

3 .3 RESULTS

Results showing the effect of intercropping resistant(TVU 946) and susceptible (ICV2) cowpea cultivars with maize during the short rains and long rains of 1987 and 1988, are shown in figures 3.1, 3.2 and 3.3, tables 3.1, 3.2 and 3.3. Figure 3.1 shows that during the short rains of 1987, *M. testulalis* larval population increased from the first sampling day (4th week after germination) and reached a peak during the second week of sampling (12th day after first sampling) (Figure 3.1) which also coincided with peak flowering period in all the cropping systems. The population then declined slightly up to the end of the season. During the entire cropping season, the incidence of *Maruca* larvae in the pure stands of both TVU 946 and ICV2 was higher than on the intercropped stands of both varieties. However the incidence of the larvae on the susceptible cultivar ICV2 when in pure stands was higher than in all other cropping systems with TVU 946 intercropped stands, having the lowest(avarage of 0.85 larvae/plant) (Fig.3.1). In general TVU 946 while in pure stands and when intercropped with maize had less *incidence of Maruca* larvae throughout the season as compared to ICV2 pure and intercropped stands (Appendeces 1 and 2).

Figure 3. 1. Incidence of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

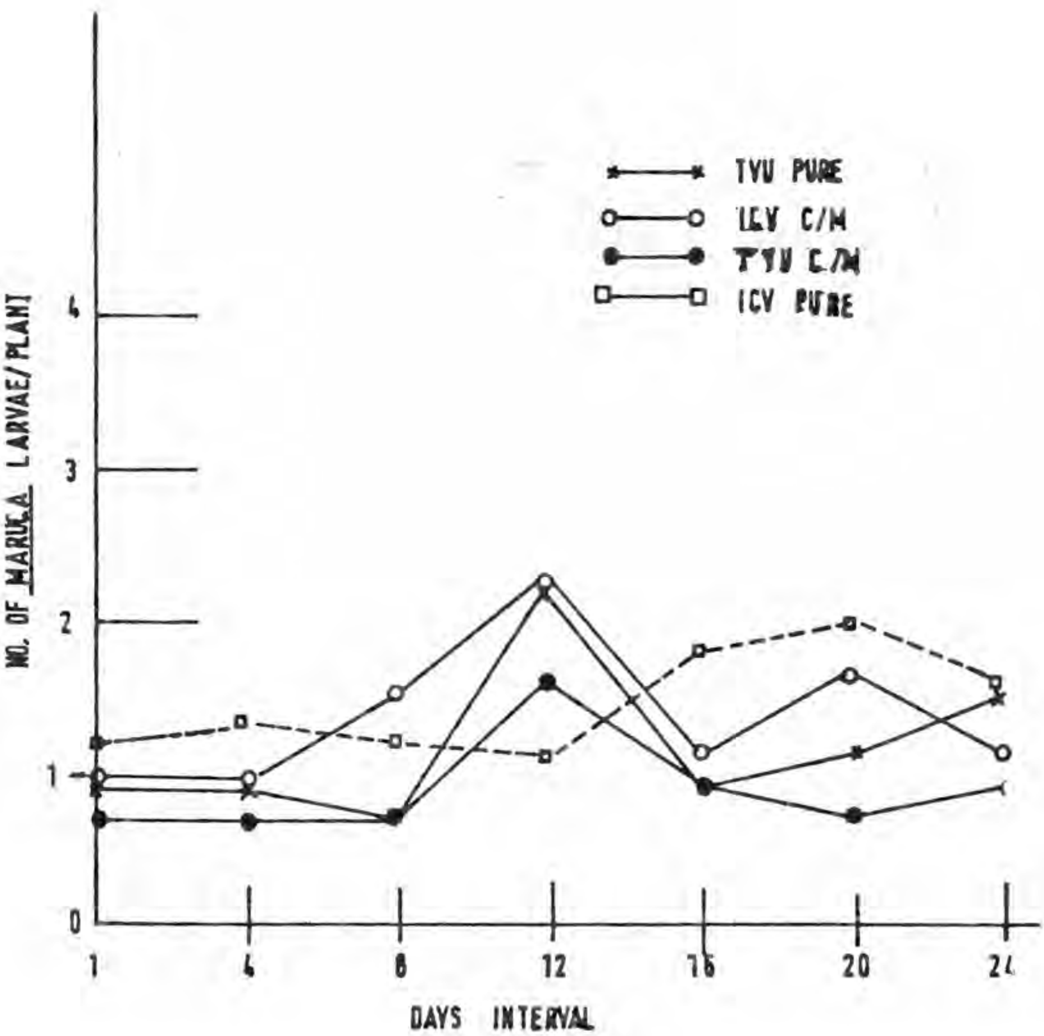


Table 3.1 shows the mean numbers of *Maruca* larvae per plant during the entire cropping season. The data from this table (3.1) shows that there were significantly (p= 0.05) fewer larvae per intercropped plant (0.91 ± 0.04) on TVU 946 intercropped than in all other treatments which were statistically similar (p = 0.05). The pooled means also indicated a significantly (p = 0.05) lower number of larvae per plant for TVU 946 pure and intercropped stands(1.29 ± 0.27) compared to ICV2 pure and when intercropped(1.37 ± 0.03) (Table 3.1 and Appendix 2).

The data on the incidence of *Maruca* larvae recorded per plant during the long rains of 1988, are shown in figure 3.2 and table 3.2. Figure 3.2 shows that unlike in the previous season where *M. testulalis* larval population increased during the first week of sampling, the population during this season increased from the second sampling interval (five weeks after germination) and reached a peak during the sixth sampling interval (6th week after germination) in all the cultivars and cropping systems. This was also the time the cowpea crop was at peak flowering period. During the second week of sampling, ICV2 in pure stands had the highest number of larvae (5 larvae/plant) which rose and reached the peak during the sixth sampling interval (Fig.3.2). The population thereafter declined up to the end of the season. Like in the previuos

Table 3.1. Mean number of Maruca larvae/plant when cowpea cultivars were planted in pure stands and when intercropped with maize (short rains 1987).

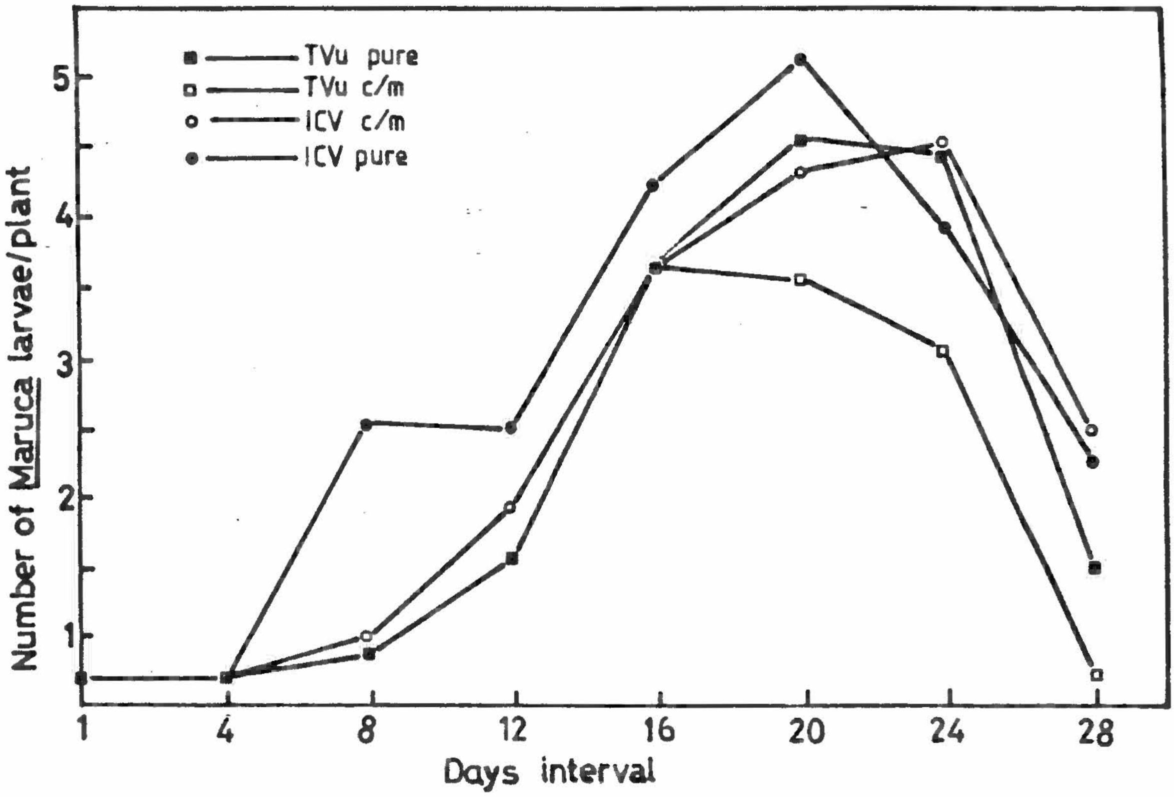
Cropping system	Number of larvae	Pooled mean
TVU 946 C/M	0.91 ± 0.04a	1.29 ± 0.27a
TVU946 pure	1.67 ± 0.13b	
ICV2 C/M	1.36 ± 0.07b	1.37± 0.03a
ICV2 pure	1.37± 0.12b	

CV = 8.47
SD ± 0.51
Means within the column followed by same letter are not significantly different at P =0.05.(Student Newmans Kuels test
Means transformed using square root x +1.

season, the incidence of *Maruca* larvae on the pure stands of TVU 946 and ICV2 was higher than on their intercropped stands. However, the incidence of *Maruca* larvae on the pure stands of ICV2 was generally higher than in all other cropping systems. During the initial two weeks of sampling, ICV2 pure stands maintained a higher larval population. From figure 3.2, it is evident that TVU 946 when interplanted with maize maintained the lowest larval population than all other cropping systems. Towards the end of the season TVU 946 had the lowest larval population compared to that of ICV2 (Appendix 3).

Table 3.2 shows the mean number of *Maruca* larvae recorded on resistant(TVU 946) and susceptible(ICV2) cowpea cultivars both in pure stands and when they were intercropped with maize over the entire cropping season (Long rains 1988). As in the previous season, the data indicated that there were significantly ($p = 0.05$) less number of *Maruca* larvae per plant (2.10 ± 0.37) on TVU 946 when interplanted with maize than when it was in pure stands(2.37 ± 0.46). Similarly the number was significantly ($p = 0.05$) lower than when susceptible cultivar ICV2 was planted in pure stands (2.65 ± 0.19 larvae/plant) (Table 3.2 and Appendix 4). However the number of larvae per plant were not significantly ($p = 0.05$) different when pure stands of ICV2 were compared with intercropped stands of the same cultivar though

Figure 3. 2. Incidence of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).



ICV2 when interplanted with maize had fewer *Maruca* larvae. The pooled means (Table 3.2) indicated that although there were no significant (p = 0.05) differences in the number of larvae per plant between varieties, TVU 946 being a resistant variety had less number(2.24 ± 0.19 larvae/plant) of larvae than variety ICV2 (2.55 ± 0.14 larvae/plant). However the data also indicated that there was a significant(p = 0.05) interaction between varieties and the cropping systems (Appendix 4).

The data on the incidence and the mean numbers of *Maruca* larvae per plant during the short rains of 1988 are shown in figure 3.3 and table 3.3 . Figure 3.3 shows that the incidence of *Maruca* larvae in all the treatments during the entire season was extremly low compared to other seasons. Also the infestation took a much shorter time than in the preceding seasons (short rains 1987 and long rains 1988). The larval population was initially higher when TVU 946 and susceptible cowpea cultivar ICV2 were planted in pure stands than when they were interplanted with maize. The larval population reached the peak during the fifth sampling interval (6th week after germination) of which as in the previuos season was the time that the cowpea crop was at peak flowering. The population then declined up to the end of the season. During the entire season, pure stands of both cowpea cultivars maintained a

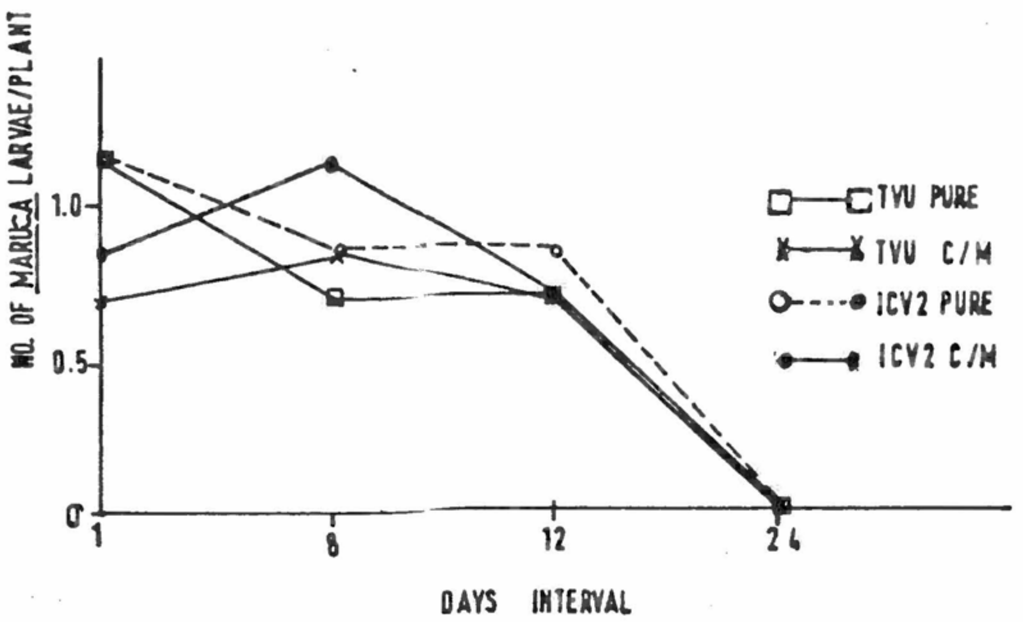
Table 3.2. Mean number of Maruca larvae/plant when cowpea cultivars were planted in pure stands and when intercropped with maize (long rains 1988)

Cropping system	No. of larvae	Pooled means
TVU 946 C/M	2.1 ± 0.37b	
		2.24 ± 0.19a
TVU946 pure	2.37 ± 0.46ab	
ICV2 pure	2.65 ± 0.19a	
		2.55 ± 0.14a
ICV2 C/M	2.45 ± 0.19a	

CV = 10.98

Means within the column followed by the same letter are not significantly diffetent at p = 0.05.(Student Newman Kuels Test).Means transformed using Sq. root x + 0.5.

Figure 3. 3. Incidence of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).



slightly higher larval incidence than the intercropped stands (Appendix 5).

Table 3.3 shows that the mean numbers of larvae per plant during the entire season was significantly ($p = 0.05$) higher when susceptible cultivar ICV2 was planted in pure stands than in all other treatments which were not statistically different. However intercropped stands of both TVU 946 and ICV2 had slightly lower numbers of *Maruca* larvae per plant (2.3 $\pm$ 0.17 and 2.30 $\pm$ 0.17 respectively) than when both cultivars were in pure stands (Table 3.3). However during this particular season there were no significant ($p = 0.05$) interactions between the cropping systems and the varieties (Appendix 6) although the pooled means indicated slightly lower numbers of larvae on variety TVU 946 (pure and intercropped) than on variety ICV2 (pure and intercropped).

Data on the mean number of pods per plant for short rains 1987 are shown in table 3.4. The total number of pods per plant were significantly ($p = 0.05$) less when TVU 946 and ICV2 (8.69 $\pm$ 1.65 and 11.0 $\pm$ 0.82 pods /plant) were in intercropped stands. This probably suggested that although TVU 946 is semi wild variety, shading by maize reduced the number of pods in both varieties. But the pooled means shows that the number of pods per plant on TVU 946 (12.77 $\pm$ 1.69) were more than those on ICV2 (12.26 $\pm$ 0.95). This probably

Table 3.3. Mean number of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean numbers	pooled means
TVU 946 pure	2.59 ± 0.25b	
		2.45 ± 0.15
TVU 946 c/m	2.30 ± 0.17b	
ICV2 pure	3.40 ± 0.58a	
		2.85 ± 0.55
ICV2 c/m	2.30 ± 0.17b	

CV = 21.63

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).

Table 3.4. Mean number of pods / plant at harvest when cowpea varieties were in pure stand and when intercropped with maize (Short rains 1987).

Cropping system	pod/plant	pooled means.
TVU 946 C/M	8.69 ± 1.65a	12.77 ± 1.69a
TVU 946 pure	16.84 ± 1.34b	
ICV2 C/M	11.00 ± 0.82a	12.26 ± 0.95a
ICV2 pure	13.53 ± 1.10a	

CV 20.89

Means in each column followed by the same letter are not significantly different at p = 0.05

explains why there were no significant ($p = 0.05$) interaction between the varieties and the cropping systems (Appendix 7).

Similarly during the long rains season of 1988, the total number of pods per plant were significantly ($p = 0.05$) less when cultivar TVU 946 was interplanted with maize (5.03 ± 3.12 pods/plant) (Table 3.5). For cultivar ICV2 (susceptible), there were no significant ($p = 0.05$) differences when it was in pure plots and when it was interplanted with maize. When both cowpea cultvars were compared using the pooled means, TVU 946 had significantly ($p = 0.05$) more number of pods per plant(9.33 ± 6.07) than cultivar ICV2 (6.92 ± 0.45 pods/plant)(Table 3.5). Unlike in the previous season (short rains 1987), there was a significant ($p=0.05$) interaction between the cropping system and the varieties (Appendix 8).

Data for the short rains 1988 showing the number of pods per plant when resistant (TVU 946) and susceptible (ICV2) cowpea cultivars were planted in pure stands and intercropped with maize indicated that, unlike in the previous two seasons, there were no significant ($p = 0.05$) differences among treatments (Tables3.6 and Appendix 9).

The percentage number of pods with *Maruca* damage symptoms (entry/exit holes) at harvesting during the short rains of 1987 (Table 3.6) shows that as in the

Table 3.5. Mean number of pods per plant at harvest when cowpea cultivars were in pure stands and when intercropped with maize(long rains 1988).

Cropping system	pods/plant	pooled means
TVU 946 C/m	5.03 ± 3.12a	
		9.33 ± 6.07a
TVU 946 pure	13.62 ± 3.86ab	
ICV2 C/M	6.60 ± 3.28a	
		6.92 ± 0.45b
ICV2 pure	7.23 ± 3.28a	

CV = 50.844

Means within the column followed by the same letter are not signicantly different at p = 0.05(Student Newmans Kuels Test).

case of pods /plant where pure stands of both TVU 946 and ICV2 had more pods per plant, the percentage number of pods with larval damage were also more (1.25 ± 0.02 and 1.32 ± 0.06 respectively) on pure stands than when both cultivars were interplanted with maize (1.14 ± 0.13 and 1.34 ± 0.01 respectively). The pooled means also indicated lower numbers of pods per plant with damage symptoms on the resistant cultivar TVU 946 than on susceptible ICV2 (Table 3.6 and Appendix 10).

Similarly, during the long rains of 1988, the percentage number of pods per plant with larval damage symptoms at harvesting (Table 3.7) were significantly ($p = 0.05$) more on pure stands of both cowpea cultivars (50.29 ± 13.35 and 50.04 ± 6.47 damaged pods/plant) than the corresponding intercropped stands (46 .69 ± 6.37 and 45.26 ± 1.11 damaged pods/plant respectively). The pooled means also indicated a slightly lower percentage of pods with damage on TVU 946 than on ICV2 though the differences were not statistically similar. This explains why there was no significant ($p = 0.05$) interaction between the varieties and the cropping systems (Appendix 11).

The data collected on the number of *Maruca* larvae/plant and pods with damage symptoms were subjected to further statistical analysis to determine the relationship between the abundance of the pest and the magnitude of the damage it caused. During the

Table 3.6. Mean number of pods /plant at harvest with *Maruca* larvae damage symptoms (% of total no. of pod/plant) when cowpea was in pure stands and when intercropped with maize (short rains 1987).

Cropping system	pods /plant	pooled means
TVU 946 C/M	(8.69) 1.14± 0.13	1.19± 0.04
TVU 964 pure	(16.84) 1.25 ± 0.02	
ICV2 C/M	(11.00) 1.34 ± 0.01	1.33 ± 0.03
ICV2 pure	(13.53) 1.32 ± 0.06	

CV = 17.00
Numbers in the brackets indicates the total no. of pods /plant.
Means transformed using Square root(X + 1)

Table 3.7 . Mean numberof pods/plant with *Maruca* larvae damage symptoms (expressed as a % of pods/plant) (long rains 1988).

Cropping systems	% pods/plant	pooled mean
Tvu 946 C/M	46.69 ± 6.37a	
		48.49 ± 2.55
Tvu pure	50.29 ± 13.35b	
ICV2 C/M	45.26 ± 1.11a	
		48.65 ± 3.37
ICV2 pure	50.04 ± 6.47b	

CV = 16.13

Means within the column followed by the same letter are not signicantly different at p = 0.05 (Student Newman Kuels Test)..

short rains of 1987. Figure 3.4 clearly shows that the coefficient of correlation was positive (r = 0.60) and indicated a significant (p = 0.05) relationship. But during the long rains(1988) the coefficient of correlation(r = 0.18) was also positive although the relationship was not significant (Fig. 3.5). This meant that the number of *Maruca* larvae/flower/pod were direct proportional to the percentage number of pods with damage, showing that as the number of larvae increased, the number of pods damaged also increased (Appendeces 12 and 13).

Table 3.9 shows the mean weight in grams per plant of damaged cowpea grains during the long rains 1988, when cultivars TVU 946 and ICV2 were planted in pure stands and when they were interplanted with maize. The mean weight of damaged grains was significantly (p = 0.05) lower when TVU 946 (resistant) was intercropped with maize than in all other treatments which were statistically similar (Table 3.8 and Appendix 14).

The preliminary data collected during the three cropping seasons (short rains 1987, long and short rains 1988) on flowerbud thrips (*M.sjostedti*) are shown in figures 3.6, 3.7 and 3.8. The data obtained during the short rains 1987 as shown in figure 3.6 a,b,and c indicated that thrips population increased from the 4th week after cowpea emergence (1st day of sampling) and reached the peak during the 12th day of

Figure 3. 4. The relationship between the number of *Maruca* larvae/plant and the percentage number of pods with damage symptoms (entry/exit holes) (short rains 1987)

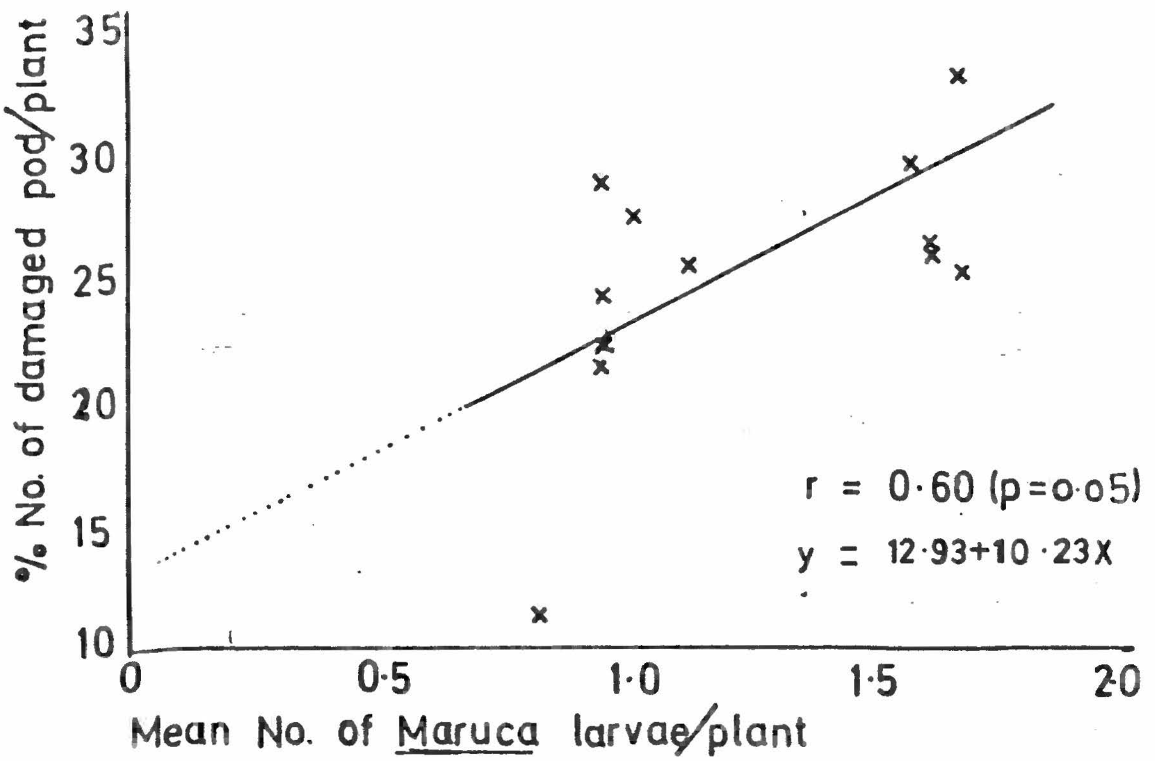


Figure 3. 5. The ralationship between the number of *Maruca* larvae/plant and the percentage number of pod with symptoms (entry/exit holes) (long rains 1988).

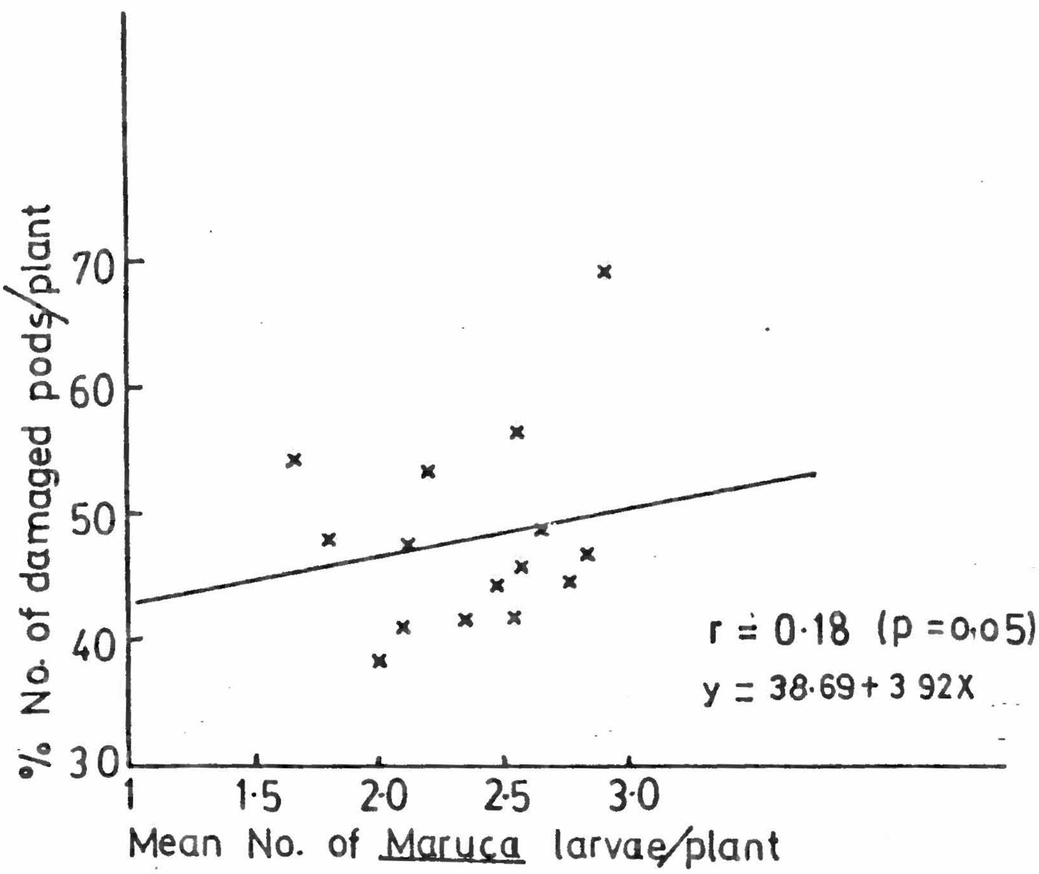


Table 3.8 . Mean weight of seeds/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Cropping system	weight in gms.	pooled means
TVU 946 C/M	0.37 ± 0.07b	
		0.44 ± 0.09a
TVU 946 pure	0.51 + 0.61a	
ICV2 C/M	0.48 ± 0.04ab	
		0.51 ± 0.04b
ICV2 pure	0.53 ± 0.11a	

CV = 23.33

Means within a column followed by the same letter are not significantly different at P = 0.05 (Student Newman Kuels Test).Means transformed using Sq. Root x + 1.

sampling (6th week after cowpea emergence) which also coincided with the peak flowering period (Figure 3.6 a, b and c). The population then dropped after the sixth week (12th day of sampling) being the period that the pods started forming. It is evident that the thrip population increase was extremly slow when the resistant cultivar TVU 946 was planted together with maize. A similar trend was observed on the susceptible cultivar ICV2 when it was also interplanted with maize though the incidence was much higher compared to that of TVU 946 (Figures 3.6 a, b and c). From the figures it can be seen that the population buildup on both cultivars was lower when they were interplanted with maize than when they were in monocrop (Appendix 15).

During the entire cropping season, intercropped resistant cowpea cultivar TVU 946 had significantly ($p = 0.05$) lower number of flowerbud thrips per plant (5.33 ± 0.11) than all other treatments which were statistically similar (Table 3.9). This indicated that intercropping reduced the number of thrips (Appendix 16).

Data obtained during the long rains season of 1988 as shown in figures 3.7 a, b, c and d indicated that thrips population increased from the first day of sampling (4th week after cowpea emergence) and reached the peak during the sixth week (12th sampling day) after crop emergence. This same trend of the

Figure 5. ...

when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

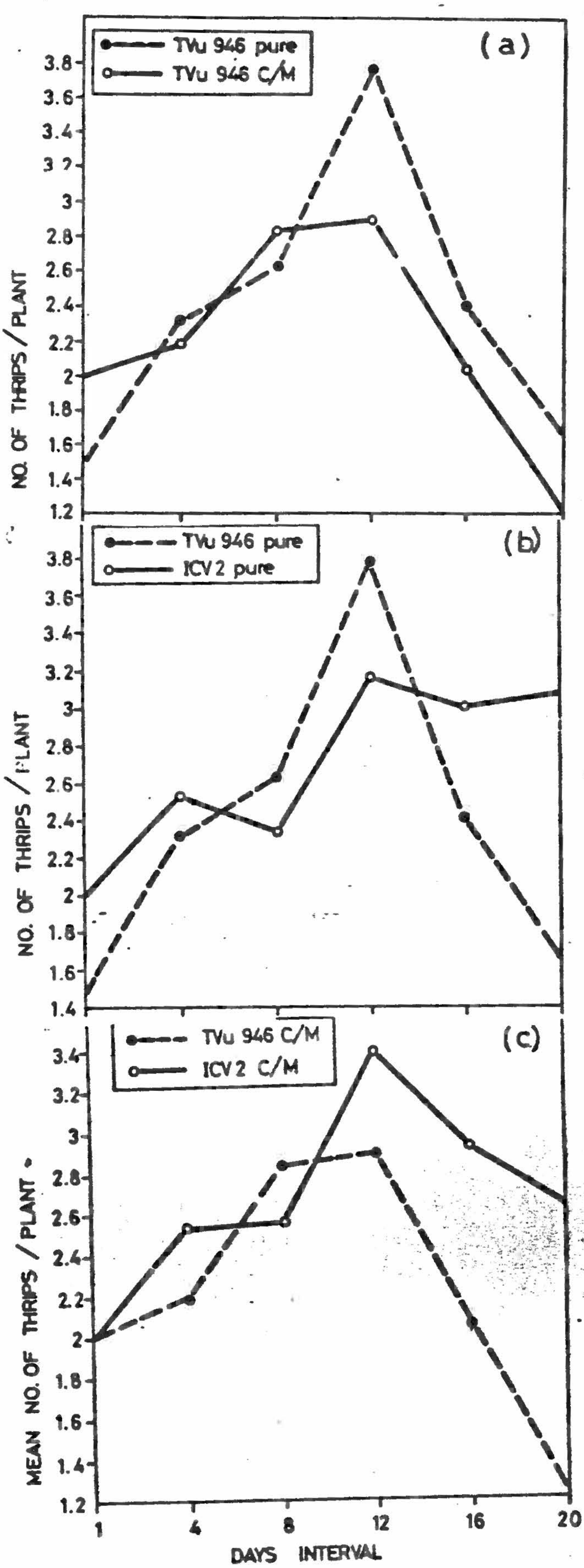


Table 3.9. Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stand and when intercropped with maize (short rains 1987)

Cropping system	No. of thrips	pooled means.
TVU 946 c/m	5.33 ± 0.11a	5.62 ± 0.21a
TVU 946 pure	5.92 ± 0.22a	
ICV2 C/M	6.31 ± 0.13a	6.38± 0.05b
ICV2 pure	6.45 ± 0,14a	

CV =9.64
Treatment means within the column followed by the same letter are not significantly different at p = 0.05 (SNK test).
Data transformed using sq. root (X + 1).

population buildup was observed during the short rains 1987. The population thereafter dropped at the time when the pods had started forming. It was evident that the thrip population buildup was extremely low when TVU 946 was intercropped with maize. The trend was somehow similar when ICV2 was also intercropped though the incidence was higher. When both TVU 946 and ICV2 were compared (Fig. 3.7a), the early flowering variety TVU 946 had an initial higher incidence of thrips which decreased after the 8th sampling day while that of ICV2 increased up to the peak podding period (Appendix 17).

The mean numbers of flowerbud thrips per plant recorded over the entire cropping season when cowpea cultivars were in pure stands and when they were intercropped with maize are shown in table 3.10. Intercropped stands of both resistant and susceptible cultivars supported comparatively lower numbers of thrips per plant (2.91 ± 0.37 and 2.95 ± 0.45 respectively) than the corresponding treatments during the entire cropping season. The differences were not statistically significant ($p = 0.05$). These results indicated that although the differences were not significant ($p = 0.05$), intercropping reduced the number of thrips per plant. Also the interaction between cropping system and varieties was not significant ($p = 0.05$) (Appendix 18).

Data on the incidence and the mean number of

Figure 3. 7. The incidence of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

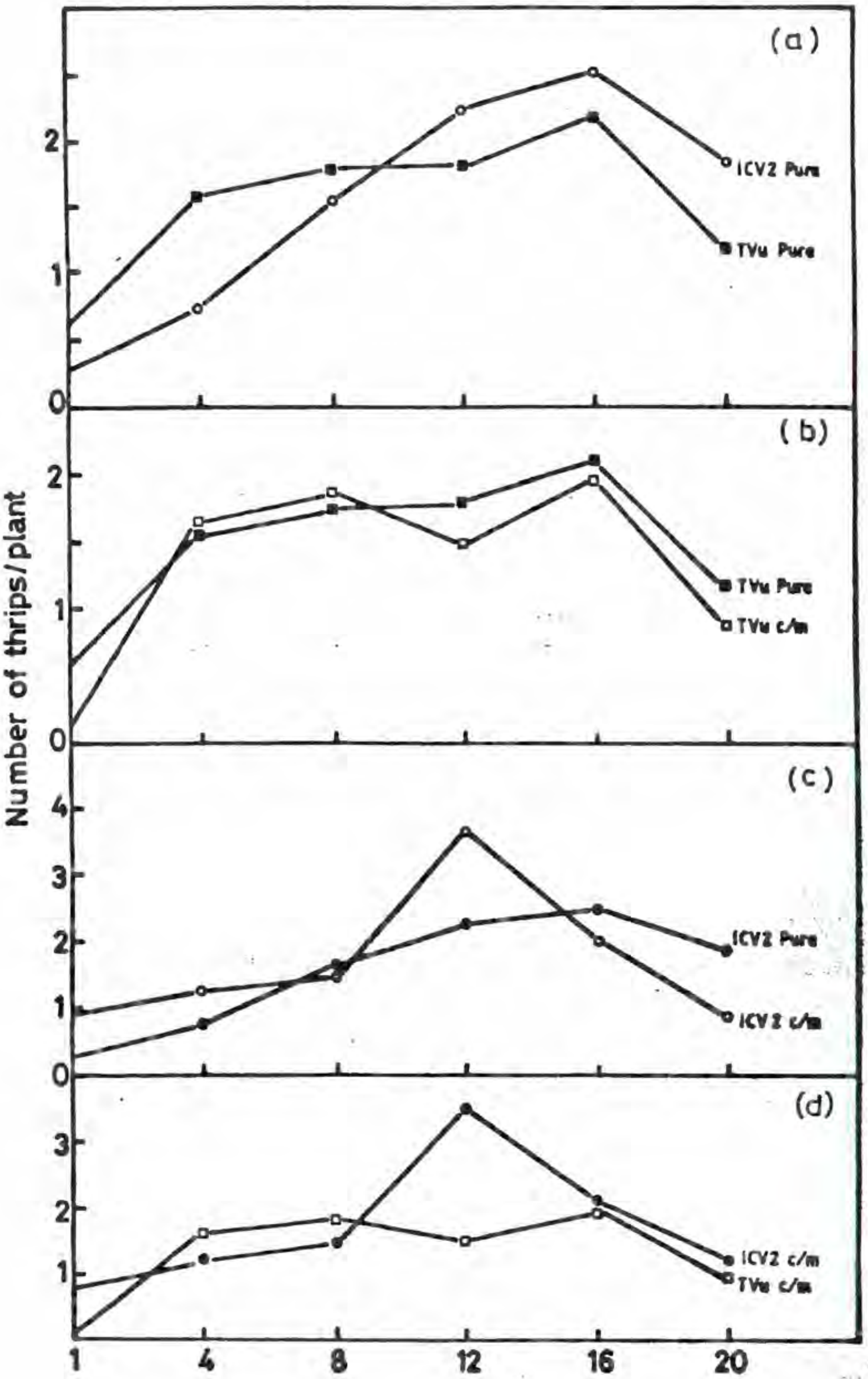


Table 3.10 . Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize(long rains 1988).

Cropping system	mean numbers	poole means
TVU 946 C/M	2.91 ± 0.37a	
		2.95 ± 0.06a
TVU 946 pure	2.99 ± 0.61a	
ICV 2 pure	2.96 ± 1.02a	
		2.96 ± 0.01a
ICV 2 C/M	2.95 ± 0.45a	

CV = 22.81 -

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).Data transformed using Sq. Root x + 1.

thrips during the short rains of 1988 are shown in figures 3.8a, b, c and d, and appendeces 19 and 20. Unlike in the previous seasons (short rains 1987 and long rains 1988), the population buildup started from the fourth week (1st day of sampling)after cowpea emergence and reached the peak during the second week of sampling (8th sampling interval) while during the previous seasons the population peaked during the 12th day of sampling. This indicated that the peak flowering period was during the fifth week after cowpea emergence. The population thereafter decreased up to the period the pods started forming. Like in the long rains (1988), the thrip population buildup was extremely low when TVU 946 was intercropped with maize as compared to other treatments (Fig.3.8 a and c). Similarly the population buildup on ICV2 when interplanted with maize was also slightly lower than when it was in pure stands (Fig. 3.8d and Appendix 20).

The mean numbers of thrips per plant obtained during the entire season are shown in table 3.11. Intercropped stands of the TVU 946 supported significantly (p = 0.05) lower numbers of thrips per plant(0.89 ± 0.10) than all other treatments which did not differ significantly (p = 0.05) although ICV2 when planted together with maize had comparatively fewer number of thrips per plant (1.26 ± 0.10) than under monocrop (1.35 ± 0.15 thrips/plant) (Table 3.11).

Figure 3. 8. The incidence of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

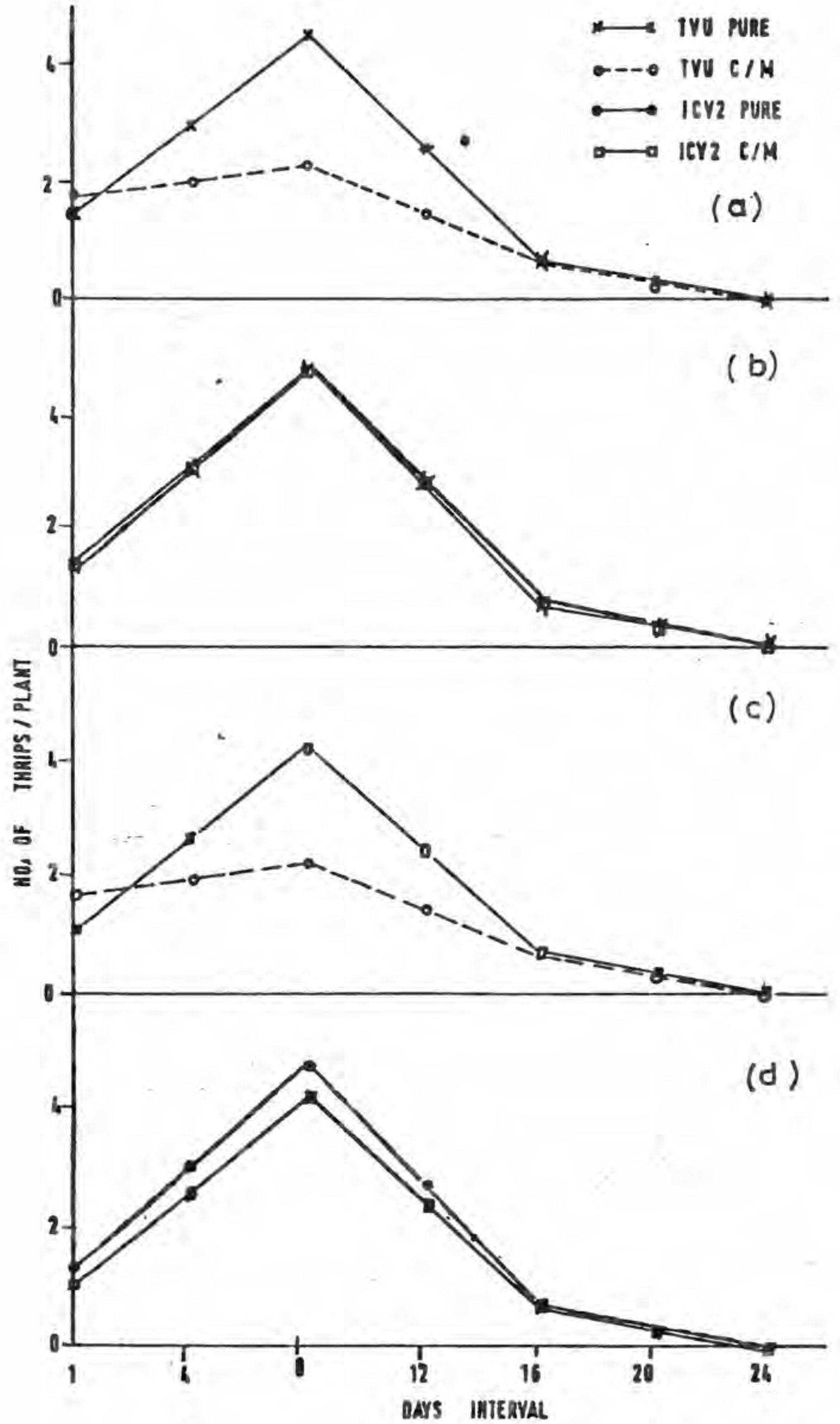


Table 3.11. Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean numbers	pooled means
TVU 946 pure	1.35 ± 0.09a	
		1.12 ± 0.23
TVU 946 c/m	0.89 ± 0.10b	
ICV2 pure	1.35 ± 0.15a	
		1.30 ± 0.05
ICV2 c/m	1.26 ± 0.10a	

CV = 15.46

Means subjected to Sq. Root x + 1 transformation.

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newmans Keuls test).

3 . 4 DISCUSSION

Data obtained from the present studies showed that there were differences between cropping systems and cultivars regarding *Maruca* larvae population in all the three consecutive cropping seasons during which the investigations were conducted. The data indicated that intercropping and resistance particularly of cultivar TVU 946 definately reduced the population build up and the subsequent number of *Maruca* larvae/plant and hence minimized the damage to flowers and pods. This agrees with Karel et. al. (1980) findings that damage to cowpea by *Maruca* larvae was more than double on pure stands than when cowpea was intrcropped with other crops like maize and sorghum.

In all the cropping seasons, it is evident that *Maruca* larvae were recorded from the fourth week after planting (28th day after germination) viz: from the first day of sampling. This period coincided with initiation flowerbuds which are the prefered stage and sites for ovipositing *Maruca* adults as reported by Taylor (1978).

It is also evident that during the first two seasons, the population build up trend was similar to that on the first week of sampling in all the varieties and cropping systems. It is evident that the arrival of the ovipositing adults was not in any way affected by the cropping system or resistance but the subsequent subsquent larval population migrating to flowers and pods were affected.

The results also revealed that there were differences in larval incidence and mean numbers between seasons in that, the incidence of *Maruca* larvae during the long rains was higher than during the short rains on both cowpea varieties. This same phenomenon was reported by Okeyo Owour and Agwaro (1982) who when using pheromone traps in their studies reported that more female adults were trapped during the long rains than in the short rains. This may also be explained by the availability of extra moisture that prolongs pod maturation, and unsynchronized production of more flowers.

Although cowpea cultivar TVU 946 is known to be highly resistant to *M. testulalis*, the combined data from the three cropping seasons reported here does not show clearly whether or not that resistance contributed to the reduction of larvae numbers. This was due to the fact that there were no significant ($p = 0.05$) differences when cultivar TVU 946 was compared with the susceptible cultivar ICV2 when both were in pure stands and of course there was lack of genotype/environmental interaction over the three seasons. It can therefore be concluded that intercropping rather than resistance caused a significant reduction on the number of larvae. This is supported by the fact that the susceptible cultivar ICV2 realised a higher population buildup and subsquent higher *Maruca* numbers in pure stands than under intercropping. Further more, the lack of significant ($p = 0.05$) differences in the numbers of larvae when both varieties were taken collectively indicated that the resistance factor did not express itself strongly.

During the cropping seasons, there was a reduction in the number of pods/plant in all the intercropped plots. The reduction could have been associated with reduced sunlight reaching cowpea due to shading by maize,resulting in shedding of flowers which later caused a reduction in the number of larvae/plant and subsquent increase in the percentage number of pods with larval damage symptoms (entry/exit holes). This observation seemed to indicate that, due to the high reduction of pods per plant, there were fewer pods that were available to the larvae in all the intercropped plots, hence the reduction in the number of pods with larval damage. However, lack of significant ($p = 0.05$) differences between treatments and also a significant interaction between cropping system and varieties was a clear indication that resistance of TVU 946 could have been modified by intercropping and environment.

Data for the short rains 1987 and long rains 1988 further revealed that the number of *Maruca* larvae per flower or pod were directly proportional to the number of pods damaged by the larvae as would be expected . This showed that as the number of *Maruca* larvae increased, the number of pods and seeds with damage symptoms also increased.

It was anticipated that since *M. sjostedti* was an important cowpea pest, its colonisation and establishment would be different in different cropping patterns. The data revealed that intercropping both varieties of cowpea with maize greatly reduced their numbers/plant in all the cropping seasons. This was due to the fact that the population build up was extremly slow when both cowpea varieties were planted together with maize, although it was less on cultivar TVU 946. However the initial population was similar in all the cropping systems and varieties during the first week of sampling (5th week after emergence) with the differences in population buildup becoming pronounced later in the season. This suggested that as in the case of *Maruca*, intercroppng did not interfere with the initial colonisation proccesses, and that the differences observed between the cropping systems were due to other factors that were operating within the system. Similarly, lack of significant differences between varieties suggested that resistance of TVU 946 to flowerbud thrips was probably interfered with by intercropping. Decrease on the number of flowerbud thrips in all the intercropped plots may have been influenced by the fact that the numbers of the flowers in an intercrop were greatly reduced. This may agree with Taylors (1971) Observations that increase in thrip population was influenced by abundance of the flowers on the crop. The decrease in flower abundance may have been caused by under production of flowers due to shading by maize.

In all the cases, resistant cowpea cultivar TVU 946 had an initial higher incidence of thrips which decreased thereafter. This was probably due to the behaviour of this variety of producing flowers earlier than cultivar ICV2. Data on thrips also revealed that the abundance of this pest was more during the short rains than during the long rains season when rains were heavier with a good vegetative growth at the expence of reproductive growth. It therefore can be concluded that in all the cases, intercropping rather than resistance or susceptibility was the main factor that contributed to the reduction in incidence and damage caused by *Maruca* and flowerbud thrips.

CHAPTER 4

THE EFFECT OF INTERCROPPING ON RELATIVE RESISTANCE AND SUSCEPTIBILITY OF COWPEA CULTIVARS TO *M. TESTULALIS* UNDER MONO AND WHEN INTERCROPPED WITH MAIZE.

4 . 1 Introduction

The magnitude and expression of resistance or susceptibility of plants to insects are influenced by environmental factors which include climate, edaphic and cultural factors of the crop environment (Singh, 1980). Simmonds (1984) stated that resistance can be adequate in some instances but inadequate else where and vice-versa. The use of resistant cowpea cultivars as opposed to susceptible ones has successfully been used in pest control (Painter, 1951; Jackai and Singh, 1983). But most of the cowpea cultivars taken to be relatively resistant or susceptible are selected for monocropping (Osiru, 1980). However it has been indicated that the expression of resistance in plants though genetic, may be modified by other factors such as insect responses and some environmental factors which determine the phenotype (Saxena, 1985). An important implication of this is that a screening program should be set up to determine whether or not resistant cowpea cultivars to various pests are likely to maintain these qualities when grown in association with other crops.

Therefore, it was considered necessary to determine the role of intercropping on the resistance and susceptibility of the above two cultivars to the infestation by *M. testulalis*.

4 . 2 Materials and Methods

As a result of the previous work by Singh and Jackai(1983) which showed the existence of cowpea resistance to *M. testulalis*, the two cowpea cultivars TVU 946 (resistant) and ICV2 (susceptible) were planted in monoculture and intercropped with maize both in the field and in a screen cage. The planting in the field was done as described in section 2 . 2 . For the screen cage experiment, cowpea cultivars were planted in plots measuring 4 m x4 m in both pure and intercropped stands which were laid down in a complete randomised block design with 4 replicates. Spacing of cowpea was 50 cm between rows and 10 cm within rows while that of maize in intercropped stands was 50 cm between rows and 20 cm within rows. All plots covering an area of 32m x 8 m were covered by a net mesh of 1.5 mm diameter to prevent any natural infestation.

Three weeks after germination, 50 pairs of newly hatched *Maruca* adults were taken from the laboratory reared larvae. These moths were then released at various points within the screen cage and allowed to mate freely and oviposit on the cowpea cultivars of their choice. To study the effect of intercropping on resistance and susceptibility of cowpea cultivars, a technique developed by Jackai(1982) and later used by Dabrowisk et. al. (1983) was applied.

4 .2 1 Open field experiment ; The assessment was carried out by taking larval counts from the cowpea crop when in pure stands and when intercropped with maize . As in section 3 . 2, sampling started from the 4th week after plating at the time when cowpea had started flowering. Sampling was done for 4 to 5 weeks depending on the season (long rains have a longer period of flowering). Larvae were counted from the samples of terminal shoots, floverbuds, flowers and pods depending on the stage of the crop. Samples were taken from a single row of a sampling cell at each sampling date. These samples were taken to the laboratory and were dissected and counts of *Maruca* larvae taken and recorded. Assessment of damage symptoms to pod and seeds was done as in section 3. 2.

To determine the effect of intercropping on the phenological characters of cowpea, and hence determining whether these characters affect resistance or susceptibility, measurements of variuos plant characters were taken. These measurements were taken at fourty days of crop emergence in both pure and intercropped stands. These included (i) plant height (ii) number of branches/plant (iii) pod length (iv) peduncle length and (v) number of leaves/plant). The measurements were taken from 10 cowpea plants uprooted randomly from pure and intercropped cowpea plots. The samples were then taken to the laboratory where the measurements were recorded.

4 .2 .2. Screen cage experiment; Measurements of damage on different parts of cowpea plants, started 10 days after the release of moths (31 days after planting) and were carried out in the following manner;

a) Stem: From a batch of 20 randomly selected cowpea plants in a row, assessment of resistance was done by carefully examining the terminal shoots, axes, main stems and branches for any larval entry exit holes (injury) or the extruded frass. The total number of damaged plants/row was determined. The damage was expressed in percentages as follows;

$$\% \text{ damage to stem} = \frac{\text{number of damaged plants}}{\text{Total no. of plants in a row}} \times 100$$

(b) Flowerbuds and flowers: Damage was assessed by taking random samples of flowerbuds and flowers at four days interval from a single row/plot. The samples were dissected in the laboratory to count the number of flowers with larvae. The damage was then computed in this form;

i) Larval counts.

ii) Percentage damaged flowerbuds and flowers as;

$$= \frac{\text{No. of flowerbuds or flowers with larval damage}}{\text{Total number of sampled flowerbus and flowers}} \times 100$$

(c) Pods; Data on pod injury were taken at crop maturity from a pre-determined harvesting plants. Each plant was examined for the number of pods damaged(entry/exit holes) and the damage was expressed as:

$$\text{\% damaged pods} = \frac{\text{No.of pods with damage}}{\text{Total No. of sampled pods}} \times 100$$

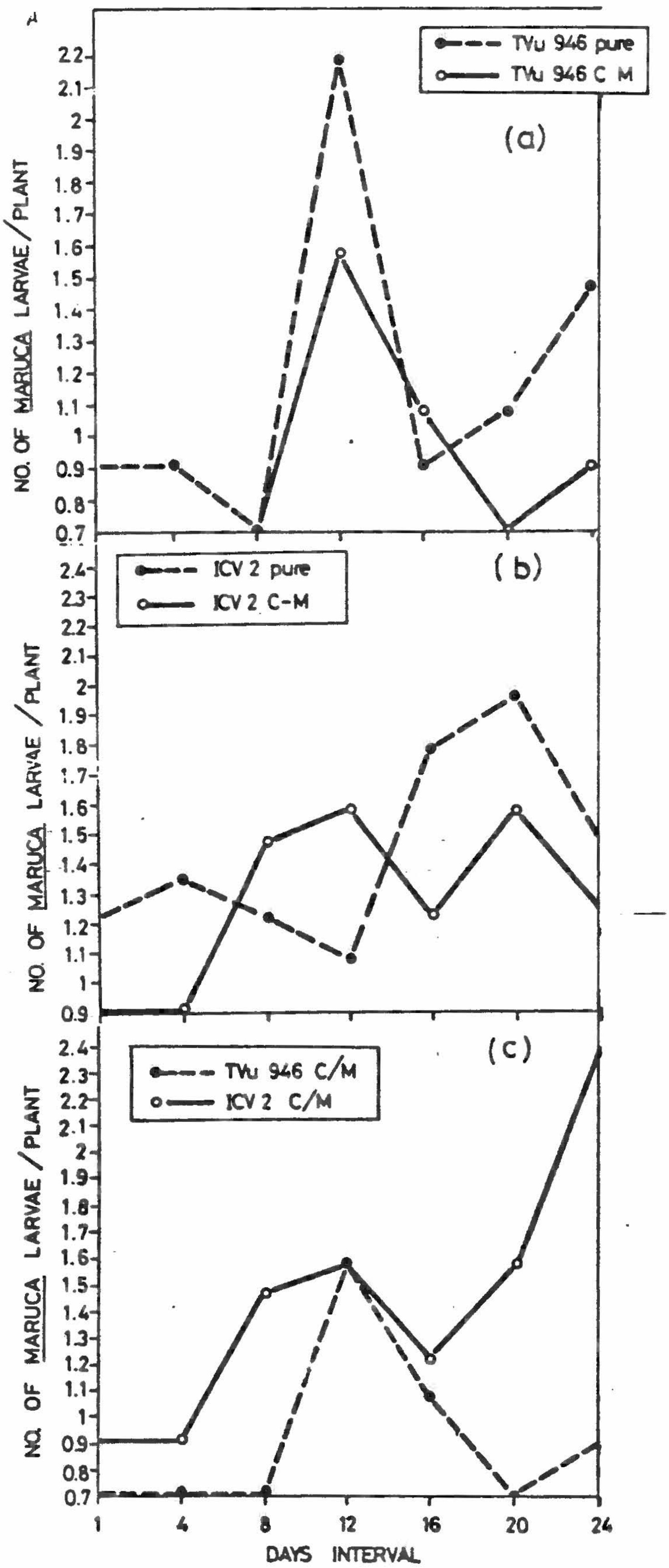
Pods from which damage was assessed were then sun dried and threshed. The seeds obtained were used to assess the total number of damaged seeds and the total seeds produced.

4 . 3 RESULTS

4 . 3. 1. Open Field Experiment

Data on relative differences in infestation by *Maruca* larvae on resistant and susceptible cowpea cultivars when in pure stands and when intercropped with maize during the short rains of 1987 are shown in figures 4.1 a, b and c, and table 4.1. Figure 4.1a shows that the buildup and establishment of *Maruca* larvae population was higher when TVU 946 was in pure stands than when it was intercropped with maize throughout the sampling period. Similarly when the population buildup on the intercropped resistant cultivar TVU 946 was compared to that on ICV2 also intercropped, the former had a lower population build up than ICV2 (susceptible)(Figure 4.1b). When the population buildup and establishment on the susceptible cultivar (ICV2) was compared, the results indicated that larval establishment on the pure stands was well pronounced during the 1st week of sampling (4th week after cowpea germination). There after the population declined during the 12th sampling interval (6th week after cowpea germination) peaking again during the seventh week after germination (20th sampling interval) (Fig 4.1c). The appearance of larvae on ICV2 when it was intercropped with maize was after the first week of sampling and the population buildup peaked during the

Figure 4. 1 Relative incidence of *Maruca* larvae on resistant and susceptible cowpea cultivars when in pure stands and when intercropped with maize (short rains 1987).



6th week and thereafter declined up to the end of the season with only a small peak during the seventh week after germination (20th day sampling interval) (Fig.4.1c). Table 4.1 also indicated that there were significant (p = 0.05) differences between the cropping systems and but between the varieties. Similarly, the number of larvae recorded differed significantly (p = 0.05) with sampling time, with the majority of the larvae recorded at the 12th sampling period(sixth week after crop emergence) (Appendix 21a).

The buildup of *Maruca* larvae population on resistant and susceptible cowpea cultivars when planted as monocrop and when it was intercropped with maize during the long rains of 1988 is shown in figures 4.2a, b, c, d and appendix 21b. Figure 4.2a shows that there were no differences in the establishment of the larvae on both resistant and susceptible cultivar during the first week of sampling (5th week after germination). Thereafter the susceptible cultivar ICV2 maintained a higher larval population than that of the resistant cultivar TVU 946. For both treatments, the larval population peaked during the third week of sampling and thereafter declined up to the harvesting time. When TVU 946 was compared with ICV2 under intercropping with maize, the population buildup on the resistant cultivar TVU 946 was lower than that on the susceptible cultivar ICV2. Similarly, the larval

Table 4.1. Mean number of Maruca larvae/plant recorded from the fourth week after germination when cowpea cultivars were in pure stands and when intercropped with maize (short rains (1987).

Cropping system	No.of *Maruca* larvae/plant							
	Days interval							
	1	4	8	12	16	20	24	mean
TVU 946 pure	0.91	0.91	0.71	2.19	0.91	1.08	1.47	1.17 ± 0.91ab
TVU 946 c/m	0.71	0.71	0.71	1.58	1.08	0.71	0.91	0.91 ± 0.12b
ICV2 pure	1.22	1.35	1.22	1.08	1.78	1.96	1.47	1.44 ± 0.12a
mean	0.94 ± 0.11b	0.97q ± 0.14b	1.03 ± 0.19ab	1.61 ± 0.23a	1.25 ± 0.19ab	1.44 ± 0.32	1.36 ± 0.15ab	

Means within the column or row followed by the same letter are not significantly different at P = 0.05 (SNK test).

population buildup on ICV2 while monocropped was higher than in all other treatments. The overall trend seen in figures 4.2a, b, c and d indicated that there were no differences in the larval establishment during the first week of sampling but the differences in the build up rate became evident during the second week of sampling and reached the peak during the third week (20th day sampling interval) to decline thereafter up to harvesting time. However it can clearly be seen from the figures(4.2a, b, c and d) that the differences in population build up and establishment were not very well defined between the two cultivars, although the population buildup on the resistant cultivar was in most cases lower than that of the susceptible one. This may have suggested that the high degree of resistance by TVU 946 was unfavourably modified by intercropping. Table 4.2. also showed differences between intercropped stands of both cowpea cultivars with no significant (p = 0.05) differences between the pure stands of both cultivars (Appendix 21c).

During the succeding season (short rains 1988), the pattern of the larval establishment and buildup was different from those of previous seasons (Fig. 4.3a, b, c, d and Table 4.3). From figure 4.3a, it can be seen that the population levels remained low and there were no remarkable differences when the resistant

Figure 4. 2. Relative incidence of *Maruca* larvae on resistant and susceptible cowpea cultivars when in pure stands and when intercropped with maize(long rains 1988).

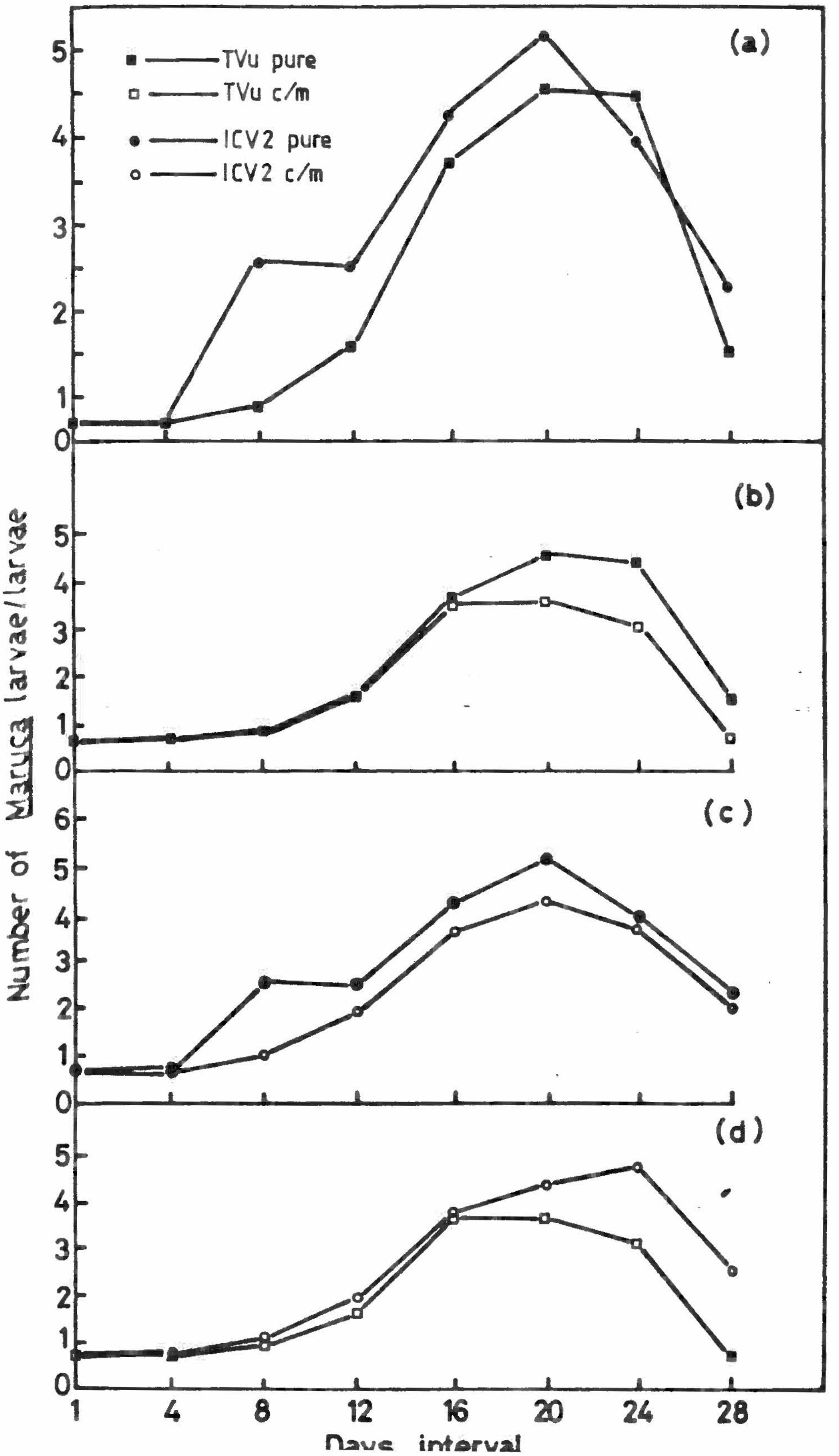


Figure 4. 3. Relative abundance of ***Maruca*** larvae on resistant and susceptible cowpea cultivars when in pure stands and when intercropped with maize(short rains 1988)..

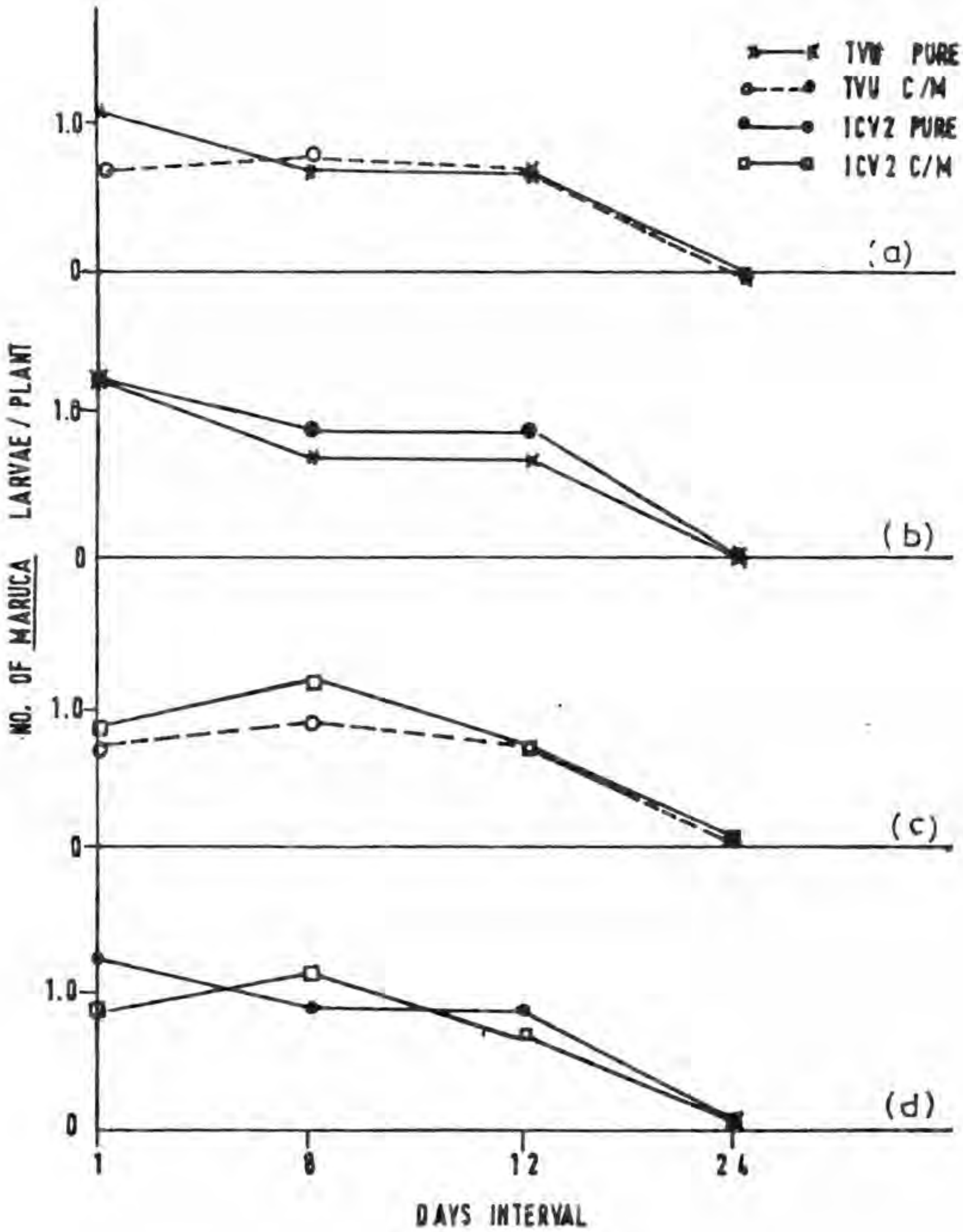


Table 4.2 Mean number of *Maruca* larvae/plant recorded from the fourth week after germination when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Cropping system	No. of Maruca larvae/plant								
	Days interval								
	1	4	8	12	16	20	24	28	mean
TVU 946 pure	0.71	0.71	0.87	1.58	3.71	4.56	4.44	1.5	2.26± 0.59bc
TVU 946 c/m	0.71	0.71	0.87	1.58	3.64	3.57	3.08	0.71	1.86± 0.48c
ICV2 pure	0.71	0.71	1.0	1.94	3.64	4.33	4.53	2.50	2.40± 0.56ab
ICV2 c/m	0.71	0.71	2.55	2.50	4.24	5.15	3.94	2.29	2.76 ± 0.57a
Mean	0.71 ±0	0.71±0	1.32 ± 0.41bc	1.9 ± 0.22b	3.81± 0.15a	4.33± 0.32a	3.99± 0.33a	1.75± 0.41a	

Means within the column and row followed by the same letter are not significantly different at P = 0.05 (SNK test).

cultivar (TVU 946) was as a monocrop and when it was interplanted with maize. The population during this season declined from the first day of sampling up to the end of the season. This same trend can be observed from other combinations as shown in figure 4.3b, c and d. However the level of the population buildup was slightly higher on ICV2 when intercropped than on TVU 946 also as an intercrop (Fig.4.3c). Table 4.3. also showed that there were no significant (p = 0.05) differences between the number of larvae recorded amongst the cropping systems and the number of larvae per sampling interval (Appendix 21c). The trend showed that during this season, the first larval population after hatching from the eggs remained constant, but declined up to harvesting. This also indicated that there was no second oviposition by *Maruca* adults.

Data from experiments on the determination on whether intercropping affect the phenology of the crop and hence resistance or susceptibilty are shown in tables 4.4, 4.5, 4.6, 4.7 and 4.8 . Table 4.4 and Appendix 22 show that there were significant (p = 0.05) differences between the height of resistant and susceptible varieties. This table also shows that there were no significant (p = 0.05) differences when TVU 946 was as a monocrop and when it was interplanted with maize. But when the susceptible cultivar (ICV2) was interplanted with maize, the plants were significantly

Table 4.3 Mean number of *Maruca* larvae/plant recorded from the fourth week after germination when cowpea was in pure stands and when intercropped with maize (short rains 1988).

Cropping system	No. of *Maruca* larvae				
	Days interval				
	1	4	8	12	mean
TVU 946 pure	1.17	0.71	0.71	0.71	0.83± 0.12a
TVU 946 c/m	0.71	0.88	0.71	0.71	0.75 ± 0.04a
ICV2 pure	1.17	0.88	0.88	0.71	0.91± 0.09a
ICV2 c/m	0.88	1.18	0.71	0.71	0.87± 0.11a
Mean	0.98 ± 0.11a	0.91 ± 0.09a	0.75 ± 0.04a	0.71 ± 0a	

Means within the column or row followed by the same letter are not significantly different at P = 0.05 (SNK test).

Table 4.4 Mean plant height at 40 days after emergence of cowpea cultivars when planted in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean height	pooled means
TVU 946 pure	20.58 ± 1.97c	
		19.32 ± 1.26a
TVU 946 C/M	18.07 ± 0.88c	
ICV2 pure	39.94 ± 3.48b	
		43.34 ± 3.62b
ICV2 C/M	47.15 ± 2.80a	

CV = 15.38.

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).

(P = 0.05) taller than when they were in pure stands (Appendix 22). However, the number of branches per plant were significantly ($p = 0.05$) more when both TVU 946 and ICV2 were in pure stands than when they were under maize (10.53 ± 0.82 and 9.17 ± 1.35 branches/plant) (Table 4.5). Their corresponding pure stands also had significantly ($p = 0.05$) less number of branches per plant (7.27 ± 0.89 and 5.67 ± 0.32) (Table 4.5 and Appendix 23). Similarly the results also showed that when the resistant variety TVU 946 was planted in pure stands, the length of the pods/plant was significantly ($p = 0.05$) less (8.52 ± 1.19 cm/pod) than when it was under maize (12.43 ± 2.64 cm/pod) (Table 4.6 and appendix 24). Similarly there were significant ($p = 0.05$) differences in pod length when ICV2 (susceptible) was as a monocrop and when it was under maize (Table 4.6). However when TVU 946 was interplanted with maize, the peduncle length was significantly ($p = 0.05$) greater than in all other treatments (Table 4.7 and appendix 25). When the susceptible cultivar ICV2 was as a monocrop, it had significantly ($p = 0.05$) more number of leaves per plant (32.73 ± 3.87) than in all other treatments which did not differ statistically (Appendix 26) although intercropped stands of both varieties had slightly less number of leaves per plant than their corresponding pure stands (Table 4.8). However there was a

Table 4.5. Mean number of branches/plant at 40 days after emergence of cowpea cultivars planted in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean numbers	pooled means
TVU 946 C/M	7.27 ± 0.89b	
		8.9 ± 1.63
TVU 946 pure	10.53 ± 0.82a	
ICV2 pure	9.17 ± 1.35a	
		7.47 ± 1.75
ICV2 C/M	5.67 ± 0.32c	

CV = 18.93.

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).

Table 4.6. Mean pod length/plant at 40 days after emergence of cowpea cultivars when planted in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean length	pooled means
TVU 946 C/M	12.43 ± 2.64a	
		10.48 ± 1.96
TVU946 pure	8.52 ± 1.19b	
ICV2 pure	12.48 ± 1.12a	
		11.49 ± 0.99
ICV2 C/M	10.50 ± 0.93ab	

CV = 24.73

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Keuls test).

Table 4.7. Mean peduncle length/plant at 40 days after emergence of cowpea cultivars when planted in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean length	pooled means
TVU 946 pure	25.50 ± 2.65b	
		30.44 ± 4.95
TVU 946 C/M	35.37 ± 2.47a	
ICV2 pure	24.50 ± 2.75b	
		26.32 ± 1.82
ICV2 C/M	28.13 ± 1.10b	

CV = 12.16

Means within the column followed by the same letter are not significantly differrent at p = 0.05 (Students Newman Kuels test).

Table 4.8. Mean number of leaves/plant at 40 days after emergence of cowpea cultivars when planted in pure stands and when intercropped with maize (short rains 1988).

Cropping system	mean numbers	pooled means
TVU 946 pure	24.5 ± 3.42b	
		23.5 ± 1.00
TVU 946 C/M	22.5 ± 7.38b	
ICV2 pure	32.73 ± 3.87a	
		25.45 ± 7.30
ICV2 C/M	18.17 ± 0.58b	

CV = 21.73

Means within the column followed by the same letter are not significantly different at p=0.05 (student Newman kuels test) significant (p = 0.05) interaction between varieties and cropping systems (Appendix 26).

4 . 3. 2 Screen Cage Experiment.

Data on the measurement of damage by *Maruca* larvae on different parts of the cowpea plant when in pure stands and when intercropped with maize are shown in tables 4.9, 4.10 and 4.11, and appendeces 27, 28 and 29.

4. 3. 2. 1. Stem Damage.

The results indicated that the susceptible cultivar ICV2 when in monocrop had significantly (p = 0.05) more number of plants per row (5.78 $\pm$ 0.48) with larval damage than in all other treatments which did not differ significantly (p = 0.05) (Table 4.9). But from the pooled means it could be seen that the differences between varieties were significantly different (p = 0.05) (Table 4.9 and Appendix 27). However interplanted resistant cultivar (TVU 946) had the lowest number (3.93 $\pm$ 0.63) of plants with *Maruca* larvae damage than in all other treatments although the differences were not significant (p = 0.05) (Table 4.9). When the percentage number of plants with damage was calculated, it was found that the resistant cultivar TVU 946 when under maize had the lowest percentage (9.63%) number of damaged plants than all other treatments. When the same variety was planted in

Table 4.9. Mean number of cowpea plant/row with Maruca damage when cowpea cultivars were planted in pure stands and when intercropped with maize (screen cage).

Cropping system	mean numbers	pooled means
TVU 946 pure	4.59 ± 0.32b	
		4.26 ± 0.33
TVU 946 C/M	3.93 ± 0.63b	
ICV2 pure	5.78 ± 0.48a	
		5.32 ± 0.46
ICV2 C/M	4.86 ± 1.28b	

CV = 23.23.

Means within the column followed by the same letter are not significantly different at $p = 0.05$ (Student Newman Kuels test).

pure stands, the damage was 22.95%. Similarly pure stands of the susceptible cowpea cultivar ICV2 suffered more damage (28.9%) than when it was under maize (24.3%). The results indicated that the susceptible cultivar ICV2 when planted as a monocrop suffered the greatest damage to stems than all other treatments (Appendix 27).

4. 3. 2. 2. Damage to flowerbuds and flowers.

The results indicated that there were significant ($p = 0.05$) differences in number of larvae between treatments (Table 4.10). Pure stands of the susceptible cowpea cultivar ICV2 significantly ($p=0.05$) had the highest number of larvae per row (1.27 ± 0.21)than in all other treatments. The flowers and flowerbuds in the intercropped stands of both cultivars had the lowest number of larvae per row although the differences were not significant($p = 0.05$) (Table 4.10). The pooled means indicated that the resistant cultivar TVU 946 had a slightly lower number of larvae per row (0.86 ± 0.14) than on ICV2 (susceptible) (0.99 ± 0.28 larvae per row). When the damage to flowerbuds and flowers was computed to percentages, the results indicated that intercropped stands of TVU 946 and ICV2 had 10% of damaged flowerbuds and flowers with larvae while pure stands of both varieties had 15 and 20% damaged flowers and flowerbuds respectively .

Table 4.10. Mean number of Maruca larvae/row when cowpea cultivars were in pure stands and when intercropped with maize (screen house).

Cropping system	mean numbers	pooled means
TVU 946 pure	1.0 ± 0.29ab	
		0.86 ± 0.14
TVU 946 c/m	0.71 ± 0.0b	
ICV2 pure	1.27 ± 0.21a	
		0.99 ± 0.28
ICV2 c/m	0.71 ± 0.15ab	

CV = 42.41

Means subjected to Sq. Root x + 0.5 transformation.

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Keuls test).

4. 3. 2. 3. Damage to pods.

Data on pod injury due to *Maruca* larvae obtained during harvesting indicated that the percentage number of pods with *Maruca* damage symptoms (exit/entry holes) was significantly ($p = 0.05$) lower when resistant cowpea cultivar TVU 946 was interplanted with maize than in all other treatments which were statistically similar (Table 4.11 and Appendix 29). The data further revealed that the differences between the cropping systems were also significant ($p = 0.05$) with monocropped TVU 946 having the highest percentage number of pods with damage symptoms (Table 4.11). Similarly when the total number of harvested damaged pods was expressed as a percentage of the total number of all harvested pods (damaged and undamaged), the data revealed that TVU 946 when planted together with maize had the lowest level of damage (20.66%) compared to other treatments (TVU 946 pure stand with 45.86%, ICV2 pure stand with 42.42% and ICV2 intercropped which had 33.14%) although when ICV2 was under maize the percentage damage to pods was slightly less than when it was in pure stands.

Table 4.11 Mean number of pods/plant with *Maruca* damage symptoms at harvest (expressed as a % of total no. of pods/plant) when cowpea cultivars were in pure stands and when intercropped with maize (screen house).

Cropping system	mean numbers	pooled means
TVU 946 pure	6.81 ± 0.11a	
		5.20 ± 1.61
TVU 946 c/m	3.59 ± 1.66b	
ICV2 pure	6.11 ± 1.37a	
		5.65 ± 0.46
ICV2 c/m	5.18 ± 1.50a	

CV = 34.77

Means subjected to Square root x + 0.5 transformation. Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newmans Keuls test).

4 .4 DISCUSSION

Data on the *M. testulalis population establishment and buildup on the resistant and susceptible cowpea cultivars in the field revealed that larval establishment was delayed until the fifth week after germination (35th day after emergence). The buildup was slower on the resistant cultivar TVU 946 when it was under maize although the differences were not pronounced. Similarly the same variety being an early maturing one had the lowest larval population unlike ICV2 which had a higher population due to its habit of producing more flower buds later in the season.*

The observation that the population buildup pattern was the same during the first week of sampling, further revealed that the initial establishement by the ovipositing *Maruca* adults was not interfered with either by the cropping pattern or the resistance ability of cultivar TVU 946. This was because TVU 946 being an early maturing variety as stated earlier produced more flower buds than cultivar ICV2 during this first week. As the season progressed, ICV2 produced more flowers and since it is a susceptible cultivar, it became more attractive to gravid females and as a result the population subsquently increased hence an overlap in the build up during the sixth week after emergence (12th sampling interval). Thereafter the population buildup was faster on cultivar ICV2 when in pure stands and when intercropped than that of cultivar TVU 946 although the differences were not very well pronounced.

The reasoning here that resistance ability of TVU 946 was reduced when it was interplanted with maize is supported by the fact that, when in pure stands, the differences in the buildup of the population between the two cultivars were very elaborate than when they were compared as intercropped stands. During the second season of 1988 the differences in infestation between the two cultivars when both were as monocrops and when under maize were minimal as the buildup of the larval population declined immediately after the initial infestation. This indicated that there were some factors probably environmental or biotic that checked the subsquent insect population buildup probably by preventing gravid females from ovipositing on the flowers.

According to Saxena (1985), resistance in plants though genetically controlled may be modified by other factors such as insect responce and environmental factors which determine the phenotype. On the bases of this arguement, the observation that the resistant cultivar TVU 946 had significantly (p = 0.05) longer pods and peduncles, and also fewer number of branches when it was under maize than when in pure stands clearly indicated that the variety was affected phenologically by the environmental conditions that were created by maize, which was not the case for cultivar ICV2 which is well adapted for intercropping as reported by Pathak and Olela (1986).

It has been observed by Ezueh (1984) that pod wall penetibility is related to the toughness of the pod wall which provides a form of tolerance to attack. However, tough and more fibrous pod wall is a characteristic of semi wild cowpea cultivars such as TVU 946. It was therefore concluded that these qualities that are the bases of TVu 946 resistance were progresively lost as the cultivar continued to be under maize. It is proposed here that since resistance of cultivar TVU 946 is also due to its pod carrying habit as reported by Jackai (1981), intercropping rendered the cultivar to be more susceptible by causing the pods and the penduncles to lengthen thus making them weaker, hence curving towards the canopy, a factor that is favoured by ovipositing *Maruca* females.

Although ovipositing *Maruca* moths are not attracted to the plant until flowerbuds are large enough as reported by Wooley (1977), screen cage experiments revealed that stems of cultivar TVU 946 were equally damaged by larvae as those of the susceptible cultivar ICV2. However the percentage damage on the stems of TVU 946 was drastically reduced when the cultivar was under maize. But the number of damaged stems in a row was the same as when it was in pure stands. In the case of cultivar ICV2 the differences among the cropping systems were clearly demonstrated, with the intercropped stands having the lowest number of damaged stems.

Similarly the small differences seen between the damaged flowerbuds and flowers in the intercropped stands and those of monocrops again indicated that intercropping progressively lowered the resitance ability of cultivar TVU 946. The results further revealed that the infestation on flowerbuds and flowers when the moths were confined in a screen cage was much higher than that on the terminal shoots in terms of percentage damage.

The percentage pod damage was significantly ($p = 0.05$) lower on TVU 946 when it was under maize which may be attributed to its early maturing behaviour thus escaping serious damage although larval infestation was generally low. There is therefore no good reason to suggest that reduced pod infestation demonstrated any resistance. These observations supports earlier field results and conclusions that although cultivar TVU 946 is said to be resistant to *Maruca* attack when planted as a monocrop, the ability to resist attack when it is interplanted with other crops is very much modified as it is not phenologically well adapted like ICV2 which has been reported to be moderately adapted for mixed cropping (Pathak and Olela 1986). This agrees well with earlier hypothesis that resistance or susceptibility of cowpea to *Maruca* is affected by intercropping.

It is pressumed that the microclimatic differences created by intercropping affect phenologically oriented traits. Trenbath (1976) had also observed that, micro-environmental differences may act on the potentially attacked crop component thereby changing its susceptibility/resistance or acting directly on the attacking organism.

In conclusion it may be said that both intercropping and the microenvironments that it creates, reduces resistance by acting directly on the crop thus rendering it more susceptible. This underlines the importance of screening resistant lines for their ability to perform well under different intercropping systems.

CHAPTER 5

COLONISATION PROCESS OF *M. testulalis* ON RESISTANT AND SUSCEPTIBLE COWPEA CULTIVARS UNDER MONOCULTURE AND WHEN INTERCROPPED WITH MAIZE.

5. 1 Introduction;

Establishment of an insect to a particular host plant involves several responses which include (a)orientation (b)feeding (c) metabolism of the ingested food (d) oviposition (e) larval growth and development (Saxena, 1985). Plant characters influecing these factors are either biophysical (eg. plant succulence, hairiness, presence of thorns and spines etc.) or biochemical (chemical compounds of secondary metabolism exuded by the plant) in nature. The expression of these factors are influenced by the environment which in some cases modify the phenotypic expression and inturn affect resistance or susceptibility of a particular plant (Saxena, 1985). As such if the plant is avoided during orientation process there could be no oviposition. It has been suggested that intercropping a non-host plant with a host plant decreases colonization efficiency and subsequent population density (Tahvainainen and Root, 1973).

It has also been reported that growing plants in monocultures in large fields tends to make them more susceptible to insects in space and time (Feeny, 1983). Omolo (1983) also reported that multiline intercropping induces associational resistance to a target pest. So far colonisation of *Maruca* females to resistant and susceptible cultivars has only been reported on cowpea as a monocrop. In view of this it was therefore, decided that the colonisation processes of *M. testulalis* with special emphasis on oviposition be investigated when resistant cultivar (TVU 946) and susceptible cultivar (ICV2) were both planted in monoculture and when intercropped with maize.

5 . 2 Materials and methods

5 .2. 1. Field experiment; Oviposition sites of *Maruca* are well known (Jackai, 1981, 1982). One week prior to flowerbud set stage , leaves , flowerbuds and flowers were carefully examined in the field using a hand lens. This exercise was carried at four days interval. Counts of the eggs were made from a single row/sampling cell and the number of eggs recorded. The data obtained was used to determine oviposition preferences on resistant and susceptible cultivars in both cropping systems.

5. 2. 2. Screen cage experiment : Cowpea cultivars were planted in plots measuring 4 x 4m in pure stands and intercropped with maize. The plots were laid down in a completely randomised block designed manner and replicated four times. The spacing was the same as that used in section 4 . 2. All the plots were then covered by a net mesh of 1.5mm before germination to prevent any natural infestation.

Fifty pairs of newly hatched *Maruca* moths taken from laboratory reared larvae were released at various points within the net cage twenty one days after germination of the cowpea. This was to allow an independent mating and oviposition on the cowpea cultivar of their choice.

Oviposition preference of the adults was measured after every two days by counting the number of eggs oviposited under choice situation in the two cropping systems. The counting was done on predetermined number of plants at the edge and at the center of each plot. The technique of counting was the same as that used in the field where all parts of the plant were examined with a hand lens and counts of the eggs recorded.

This was done at four days intervals and the data obtained was used to determine the suitability of the two cultivars for adult oviposition. This exercise continued until no more eggs were found in the field.

5. 3. RESULTS

5. 3. 1. Open Field Experiment.

Data on the oviposition preference by *Maruca* adults during the short rains of 1987 on both susceptible and resistant cowpea cultivars (pure and intercropped) are shown in figures 5.1a, b, c and d. The data revealed that in all the combinations, the differences between the number of eggs laid per plant were not clearly marked at the beggining of the sampling period up to 12th day of sampling (5th week after germination). Thereafter the number of eggs per plant increased in all the treatments. Figure 5.1a shows that after the 12th sampling day, the number of eggs per plant increased progressively when TVU 946 was in pure stands than when it was intercropped. Similarly when both cowpea cultivars were compared while they were in intercropped stands (Fig. 5.1b), the number of eggs oviposited on the susceptible cultivar ICV2 was higher than those oviposited on the resistant cultivar TVU 946 up to the end of the sampling period. When the susceptible cultivar ICV2 was compared in pure stands and when intercropped with maize the number of eggs oviposited after the 12th day of sampling were more less the same (Figure 5.1). A similar situation was observed when pure stands of both cultivars were compared (Fig. 5.1d) although the number of eggs laid on TVU 946 (resistant) (Appendix 30a, b and c) were less than those laid on the susceptible cultivar ICV2, suggesting that resistance or susceptibility qualities were still not very much affected by intercropping during the colonisation process. Table 5.1 supported the above results by the fact that significant ($p = 0.05$) differences were observed between the cropping systems, and also the number of eggs recorded in all the cropping systems significantly ($p = 0.05$) differed with plant age (Appendix 31a).

A similar situation on oviposition preference was observed during the long rains of 1988 as shown in figures 5.2a, b c and table 5.2 . The figures clearly show that the differences in oviposition preference were clearly marked after the 12th day of sampling. Figure 5.2a indicates that after the 12th day of sampling, the number of eggs oviposited on the pure stands of TVU 946 were more than those that were oviposited when the cultivar was interplanted with maize. Figure 5.2b also revealed that the number of eggs laid on the susceptible cultivar ICV2 when in pure stands were slightly more than those that were laid when the variety was interplanted with maize. But when the

Figure 5. 1. Abundance of *Maruca* eggs/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

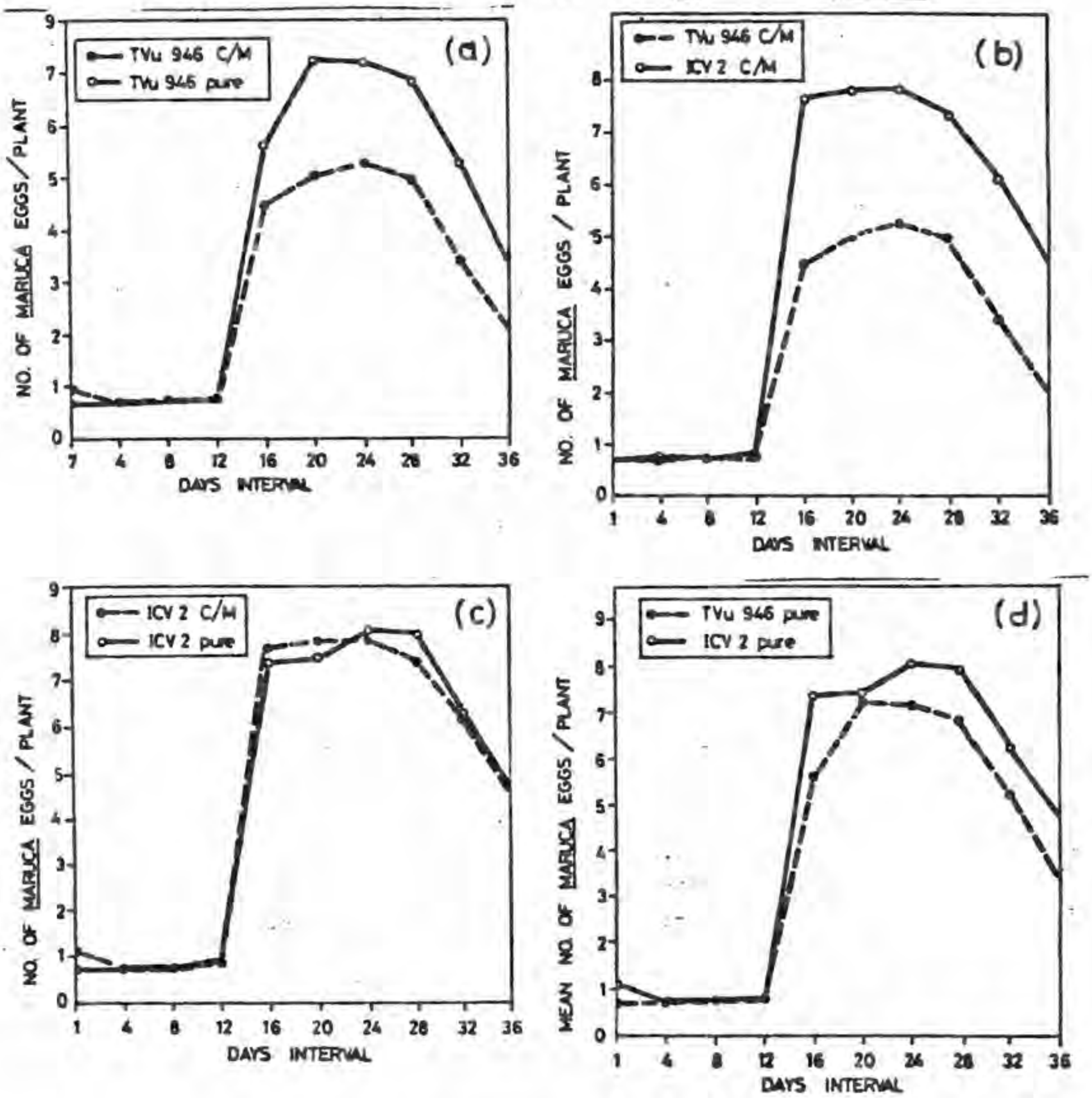


Table 5.1 Mean number of Maruca eggs/plant recorded from the third week after germination when cowpea was in pure stands and when intercropped with maize (short rains 1987).

Cropping system	No. of eggs/plant Days interval 1	4	8	12	16	20	24	28	32	36	Mean
TVU 946 C/M	0.71	0.71	0.73	0.76	4.48	5.02	5.27	4.97	3.43	2.06	2.81± 0.64c
TVU 946 pure	0.71	0.71	0.76	0.79	5.63	7.24	7.18	6.85	5.28	3.37	3.85± 0.92b
ICV2 pure	1.10	0.79	0.82	0.71	7.38	7.44	8.08	7.94	6.28	4.76	4.53± 1.04a
ICV2 C/M	0.89	0.77	0.71	0.87	7.68	7.82	7.84	7.40	6.13	4.51	4.96± 1.04ab
Mean	0.85 0.05d	0.75± 0.02d	0.75± 0.01d	0.78± 0.02d	6.29± 0.75a	6.88± 0.63a	7.09± 0.63a	6.80± 0.65a	5.28± 0.65b	3.68± 0.62c	

Means within the column and those along the same row followed by the same letter are not significantly different at p = 0.05 (Student Newmans Kuels test).

Table 5.2. Mean number of Maruca eggs/plant recorded from the third week after germination when cowpea was in pure stands and when intercropped with maize(long rains 1988).

Cropping system	No. of eggs/plant					
	Days interval					
	1	4	8	12	16	Mean
TVU 946 pure	0.76	0.89	1.04	1.28	1.77	1.15 ± 0.18bc
TVU 946 C/M	0.71	0.74	1.02	1.26	1.28	1.00 ± 0.12c
ICV2 C/M	0.71	0.92	1.44	1.77	1.88	1.34 ± 0.23ab
ICV2 pure	0.79	1.05	1.36	1.66	2.34	1.44 ± 0.27a
Mean	0.74 ± 0.02d	0.90 ± 0.06d	1.22 ± 0.11c	1.49 ± 0.13b	1.82 ± 0.22a	

Means within the column and those along the same row followed by the same letter are not significantly different at p = 0.05 (Student Newmans Kuels test).

intercropped stands of both cowpea cultivars were compared, the differences between the number of eggs oviposited were clearly marked after the 4th day of sampling with the susceptible cultivar(ICV2) having the highest number of eggs (Figure 5.2c). This was a clear indication that the susceptible cultivar (ICV2)(pure and intercropped) was more preffered than the resistant cultivar TVU 946 (Appendix 32). Table 5.2 also showed significant(p = 0.05) differences between the cropping systems and between plant age preference (Appendix 31b).

Unlike in the two previous seasons (short rains 1987 and long rains 1988), the data on oviposition preference obtained during the short rains of 1988 showed that there were more eggs per plant that were oviposited during the first week of sampling (third week after germination)(Figures 5.3a, b, c, d and Table 5.3) of which were later reduced on both cultivars up to the 12th day of sampling (5th week after germination). Thereafter the number of eggs recorded increased up to the end of the sampling period in all the cropping systems. However, the trend was somehow the same as in the previous seasons in that when the number of eggs per plant were recorded, the resistant cultivar TVU 946 when in pure stands had more

Figure 5. 2. Abundance of ***Maruca*** eggs/plant when cowpea cultivars were in pure stands and when intercropped with maize(long rains 1988).

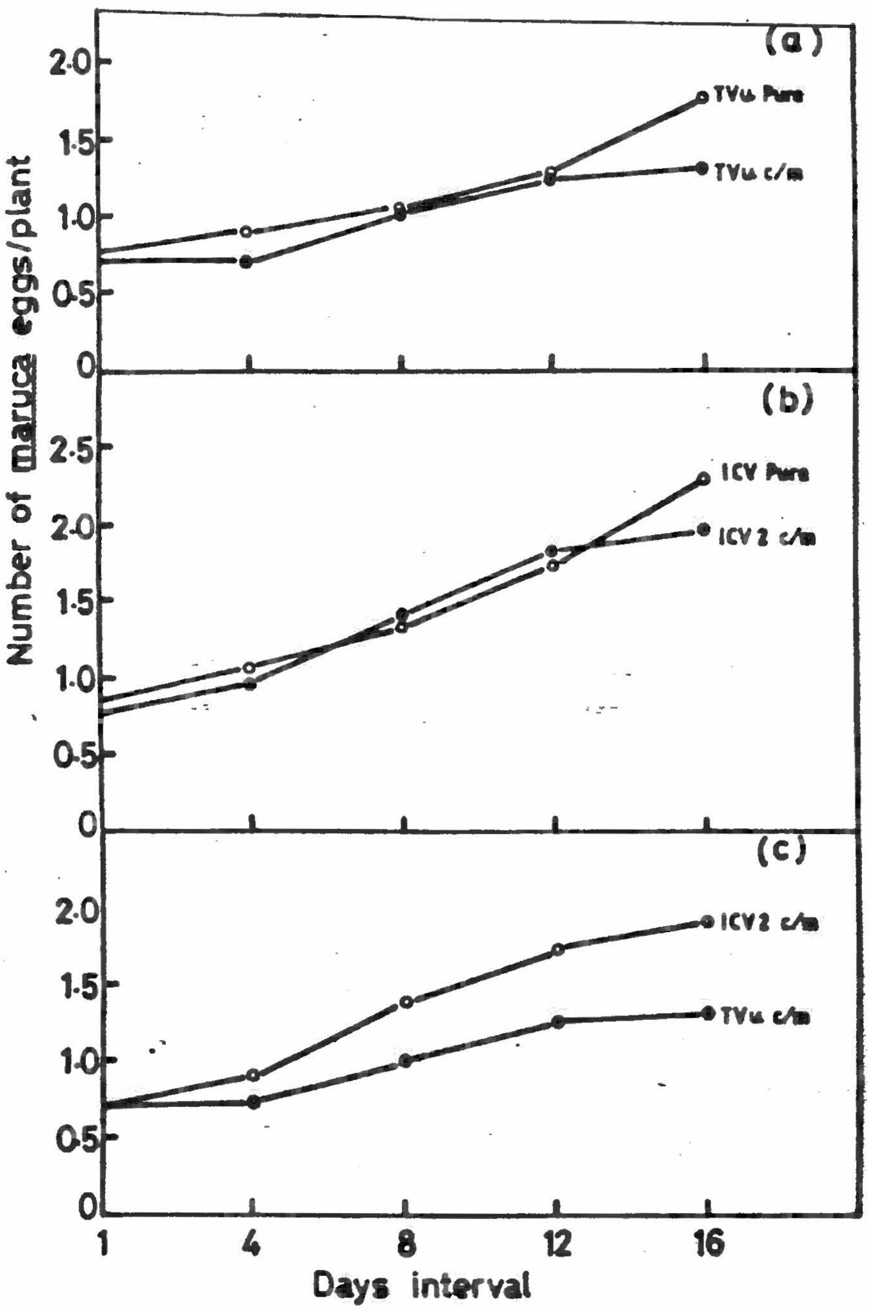


Table 5.3 Mean number of Maruca eggs/plant recorded from the third week after gemination when cowpea was in pure stands and when intercropped with maize(short rains 1988).

Cropping system	No. of eggs/plant Days interval 1	4	8	12	Mean
TVU 946 pure	2.00	1.34	1.17	4.25	2.19 ± 0.71b
TVU 946 C/M	1.81	1.05	1.82	1.29	1.49 ± 0.19b
ICV2 pure	4.52	2.15	6.36	5.19	4.56 ± 0.88a
ICV2 C/M	1.17	1.57	2.43	1.91	1.29 ± 0.29b
Means	2.51 ± 0.67a	1.52 ± 0.23a	2.95 ± 1.17	3.16 ± 0.93a	

Means within the column and those along the same row followed by the same letter are not significantly different at p = 0.05 (Student Newmans Kuels test) numbers of eggs per plant than when it was intercropped with maize (Fig.5.3a). Similarly more eggs were recorded on the susceptible cultivar ICV2 when planted as pure stands and when interplanted with maize than on TVU 946(resistant) also as a monocrop and when intercropped with maize (Fig. 5.3b and c). Figure 5.3d and table 5.3 further indicated that significantly more eggs were oviposited on the pure stands of the susceptible cultivar ICV2 than on the intercropped stands of the same cultivar ICV2 (Appendix 31c).

5. 3. 2. Screen Cage Experiment

Data on the experiment to determine the suitability of *Maruca* adult oviposition preference under screen cage are shown in figures 5.4a, b, c, d and table 5.4 and appendix 34.

Figure 5.4a shows that differences between the number of eggs recorded at the edge and at the center of pure plots of both TVU 946 and ICV2 were not clearly marked. However differences in the number of eggs per plant were observed between the edges and the centers of all intercropped plots of TVU 946 (Fig. 54b). The differences were clear after the 8th day of sampling. Similarly the number of eggs recorded on the edges of the intercropped plots of susceptible cultivar ICV2,

Figure 5. 3. Abundance of *Maruca* eggs/plant when cowpea cultivars were in pure stands and when intercropped with maize(short rains 1988).

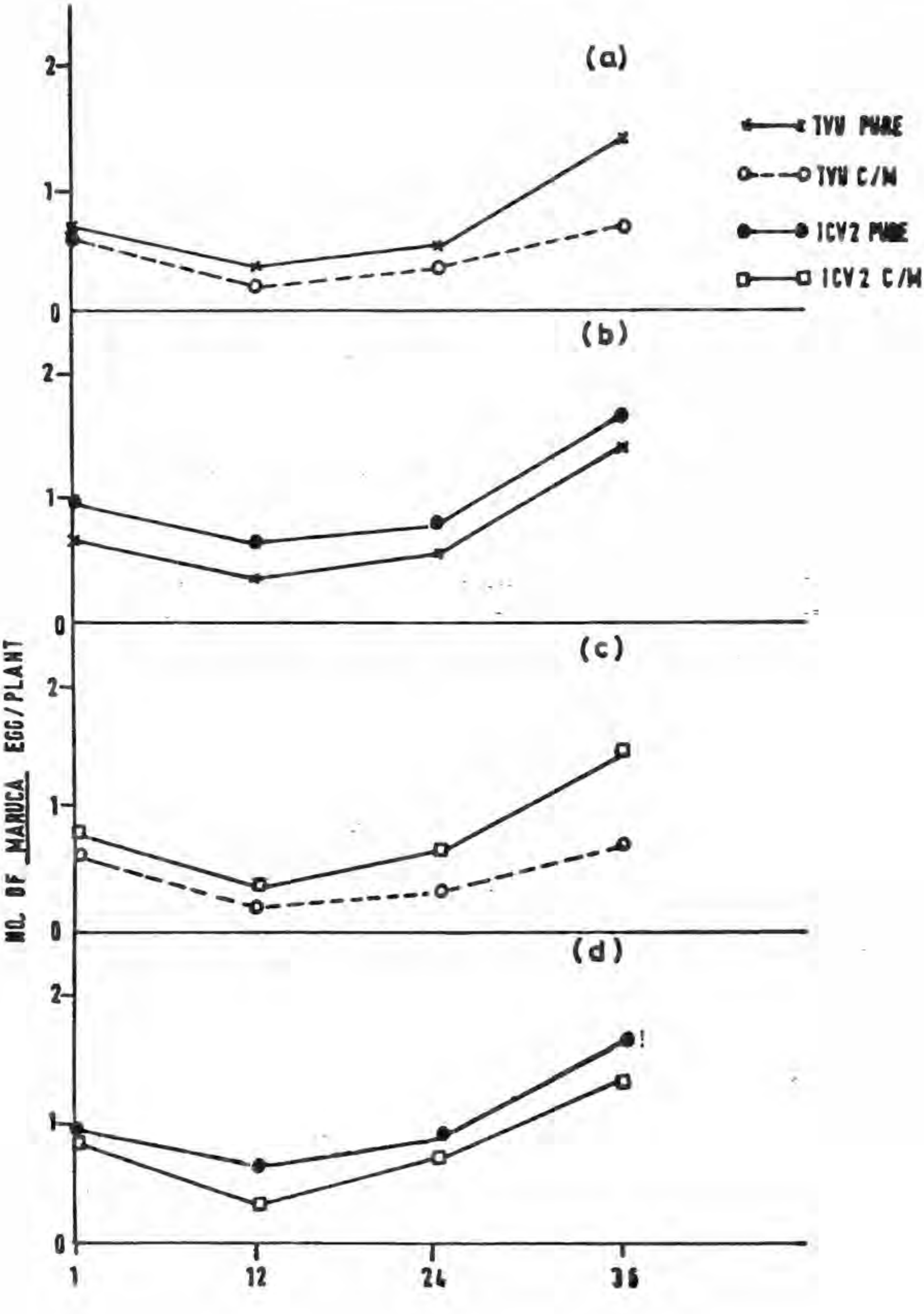


Table 5.4. Mean number of Maruca eggs/plant recorded at the centers and at the edges of cowpea plots when the cultivars were in pure stands and when intercropped with maize (screen house).

Cropping system	mean numbers center	edge	total	pooled means
TVU 946 pure	1.28 ± 0.15b	1.23 ± 0.14b	1.26 ± 0.03b	
				1.08 ± 0.11a
TVU 946 c/m	0.85 ± 0.25c	0.94 ± 0.21c	0.89 ± 0.05a	
ICV2 c/m	1.25 ± 0.09b	1.27 ± 0.14b	1.26 ± 0.01b	
				1.33 ± 0.05b
ICV2 pure	1.46 ± 0.12a	1.33 ± 0.09b	1.39 ± 0.07b	
Mean	1.21 ± 0.13a	1.19 ± 0.08a		

CV = 17.74

Data subjected to Sq. Root x + 1 transformation.

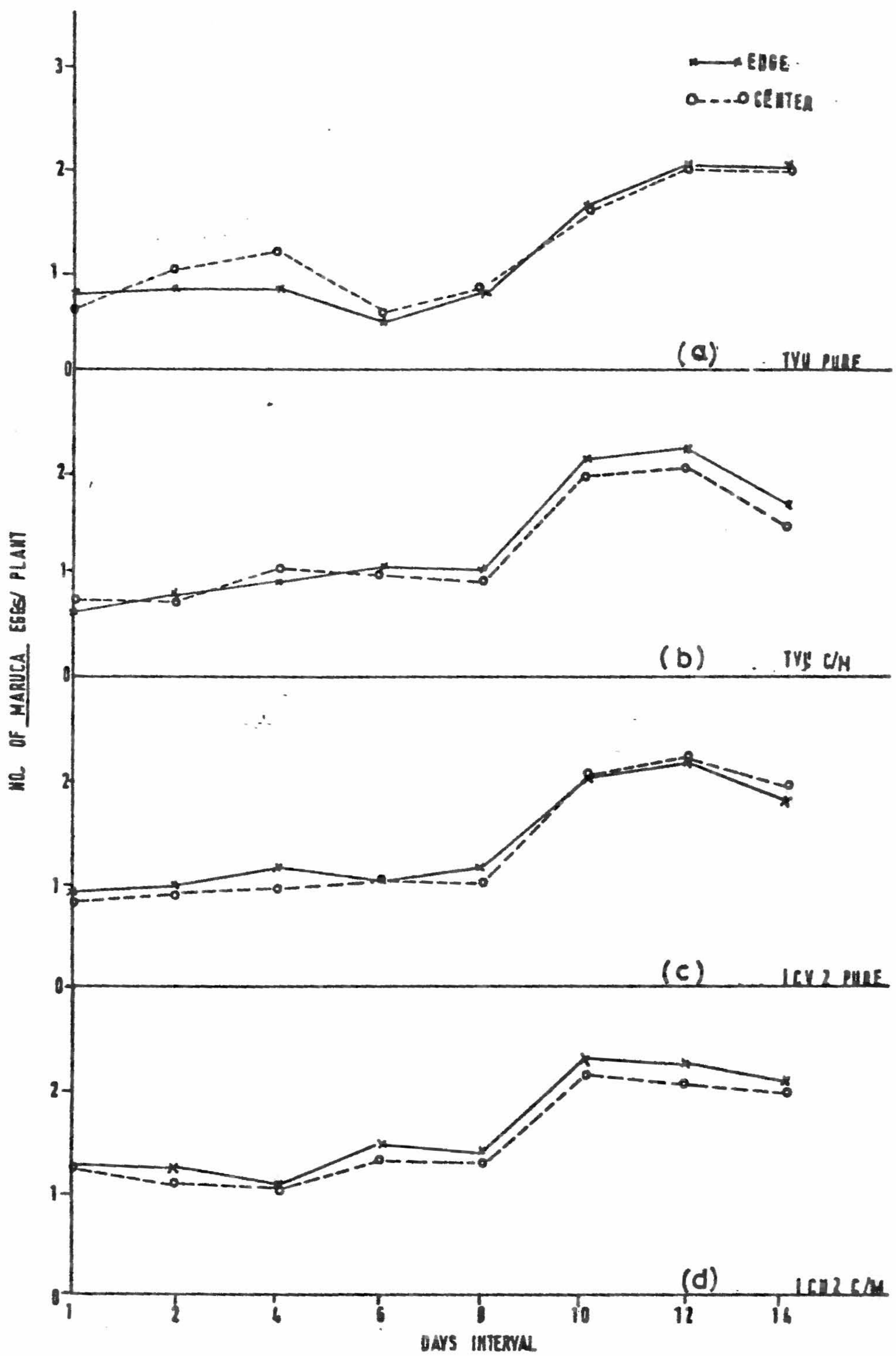
Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newmans Kuels test).

were more than those recorded at the centers of the same plots(Fig. 5.4d) (Appendix 34).

Table 5.4 shows the mean number of eggs recorded at the edges and at the centers of all the treatments. This table indicates that although there were no significant ($p = 0.05$) differences between the edges and the centers, slightly more number of eggs were recorded at the edges of both resistant (0.94 ± 0.21 eggs per plant) and susceptible cultivars (1.27 ± 0.14 eggs per plant) when both were intercropped with maize (Appendix 35).

The overall data as shown clearly shows significant ($p = 0.05$) differences in oviposition preference between varieties and also between the cropping systems. This indicated that both intercropping and resistance contributed an additive effect on the ovipositing *Maruca* adults.

Figure 5. 4. Abundance of *Maruca* eggs at the edges and centers of cowpea plots when in pure stands and intercropped with maize (screen cage).



5. 4 DISCUSSION.

The observation that the initial oviposition during the third week after emergence, very few eggs were recorded on all the treatments revealed that there was a plant age preference for oviposition on the cowpea cultivars. This was due to the fact that the first batch of the eggs appeared on the plants at the beggining of the fourth week (28 days after emergence) after emergence and thereafter there was a frequency buildup to the seventh week after emergence in all the treatments. The fourth week after emergence coincided with flowerbud initiation. According to Taylor (1978), the buds and flowers are the prefered sites for the ovipositing *Maruca* females. This also may explain why there were no eggs that were recorded after the seventh week after emergence (the time the crop was at peak podding stage).

Differences observed in the relative abundance of *M. testulalis* eggs on different cultivars and cropping patterns suggested that resistance or susceptibility and intercropping played a major role in controlling the ovipositing *Maruca* adults. The underlying role of intercropping is very clear in that, after the 12th day of sampling (5 weeks after emergence), more eggs were recorded on the pure stands than on plots where cowpea was planted together with maize. Also during the short rain seasons, the role of resistance was clear in that, more eggs were recorded on the susceptible cultival ICV2 than on the resistant cultivar TVU 946. However during the long rains the differences between cultivars and cropping patterns were not very distinct. These differences observed in the field especially during the short rains may be attributed to the fact that, the incidence of the pest was very low (also seen in section 3.3). Therefore the few adults that were present prefered to lay their eggs on the readly accesible pure plots rather than the intercropped plots. During the long rains, the differences between the number of eggs observed were negligible until after the sixth week of crop emergence. (12th day samling interval).

The observation that in some cases more eggs were recorded on ICV2 when in pure stands than when intercropped clearly suggests that intercropping was actually the main factor that caused *Maruca* adults to lay fewer eggs.

Detailed studies in a confined environment (screen cage) to confirm the above inferences showed that more eggs were found at the edges than at the centers of all the intercropped plots and that they were evenly distributed in all sole planted cowpea. This is in agreement with Kayumbo et. al.(1976) that, when cowpea is intercropped with maize, fewer ovipositing adults enter the intercrop. The data further revealed that there were differences in oviposition between varieties, suggesting that the resistant cultivar TVU 946 may have not been attractive to the ovipositing females due to its pod currying habit unlike on the cultivar ICV2 where the peduncles are within the canopy favouring the ovipositing adults.

Although in earlier experiments (section 4.4) it was shown that resistance of TVU 946 was modified under intercropping with maize, one would conclude that due to the phenological changes observed, oviposition preference between cultivars and cropping patterns was distinct. The potential of TVU 946 as a resistant variety when planted as a sole crop is therefore apparent. However as noted earlier in section 4.4, that the incidence of the larvae between pure and intercropped plot was the same for cultivar TVU 946, it may be suggested that it was the larval populations of the following generation that were not affected by the resistance traits of cultivar TVU 946 as a result of the phenological changes that were observed when the cultivar was under maize which most probably rendered it more acceptable by the larvae. This aggrees with Van Emden(1976) observation that the host plant can greatly influence not only the amount of colonisation but also natality or mortality of the subsquent stages.

CHAPTER 6

MICROENVIRONMENTAL DIFFERENCES BETWEEN PURE COWPEA AND COWPEA/MAIZE INTERCROPP.

6 . 1 Introduction

The presence of a companion crop in an intercropped ecosystem creates a microenvironment which differs from that found in a monoculture (Trenbath, 1976). These micro-environment differences affect the host parasite relationship by influencing the population of natural enemies or by acting directly on the plants changing its susceptibility or resistance or by acting directly on the attacking organism (Trenbath, 1976; Perrin, 1977). In an intercropped ecosystem, there is increased shading, humidity and lowered temperatures depending on the crop combination. These parameters either favour or do not favour the pest population build up (Ochieng, 1977; Matteson, 1982; Way, 1983).

The microenvironmental differences and their effect on resistance and susceptible cowpea cultivars when in pure stand and when intercropped with maize have not been fully studied. In this chapter the above lacking information has been looked at with reference to *M.testulalis* population build up in an intercropped ecosystem.

6 . 2 Materials and methods

To determine the effects of temperatures and relative humidity, thermohydrograghs were placed at the centre of each plot in both cropping systems from where daily records were taken from time of germination to harvesting. The thermohydrograghs were placed in mesh wire cages which were placed just above the cowpea canopy (about one third of a metre from the soil surface). Solar radiation reaching the cowpea canopy was measured using a solar radiometer. The amount of light recorded in the intercropped stands was substracted from one recorded in the pure stands so as to get the amount of light intercepted by maize in the intercropped stands.

The data obtained was used to determine whether microclimatic differences created by intercropping had any effect on the infestation of *Maruca*.

6.3 RESULTS

Data taken on the interception of sunlight incident on cowpeas by maize in the intercropped stands during the three consecutive rainy seasons (short rains 1987, long and short rains of 1988) are shown in figures 6.1, 6.2a and 6.2b. It can be seen that light interception during the three consecutive rainy seasons followed the same pattern from the first day of crop emergence. During the first week of crop emergence very little light was intercepted. But at the beginning of the second week of crop emergence light interception followed a logarithmic pattern where more and more light was progresively intercepted. Thereafter the intercepted sunlight incident on cowpea stabilized up to harvesting time depending on the season (Figures 6.1, 6.2a and 6.2b). This was due to the progressive canopy increase as the maize grew taller.

Data showing the trends of the mean temperatures and relative humidities for the three cropping seasons are shown in figures 6.3, 6.4 and 6.5 . Figure 6.3 shows that during the short rains of 1987, the mean temperatures recorded from pure cowpea stands was higher than that which was recorded from the cowpea/maize stands. To the contrary, the percentage relative humidity trends over the entire season indicated that the RH was higher in the cowpea/maize intercropp than in the pure cowpea plots. As shown in figures 6.4 and 6.5 , the trend was very much the same during the long and the short rain seasons of 1988. However during the first week of germination, records for these parameters were the same as the maize had not covered the cowpea as they were planted simultaneously. The differences became clearer later in the season. Figures 6.4 and 6.5 show that during the cropping seasons of 1988, the differences in % RH sometimes overlapped between the cropping patterns. This was attributed to the irregularity in the rainfall pattern and other environmental changes (eg.temperatures) especially during the time the records were taken. All in all seasonal temperatures showed marked differences bettween cropping patterns, while percentage relative humidities also showed slight differeces between cropping patterns (Appendix 39, 40 and 41).

The data on mean weekly air temperatures and % Rh for the three cropping seasons as shown in tables 6.1, 6.2 and 6.3 and appendices 39, 40 and 41 indicated that there were significantly ($p = 0.05$) higher temperatures and significantly ($p = 0.05$) lower Rh in the pure stands of cowpea than in the intercropped stands which had lower temperatures and higher Rh respectively.

Figure 6. 1. Light intercepted by maize__ in cowpea/maize ——
intercrop(short rains 1987).

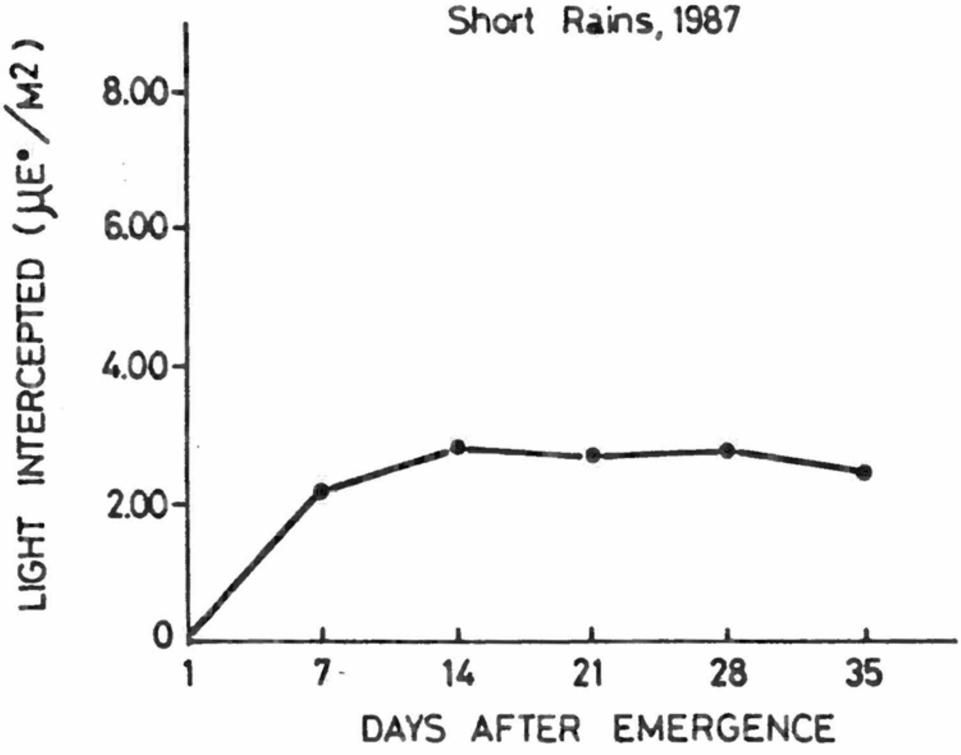
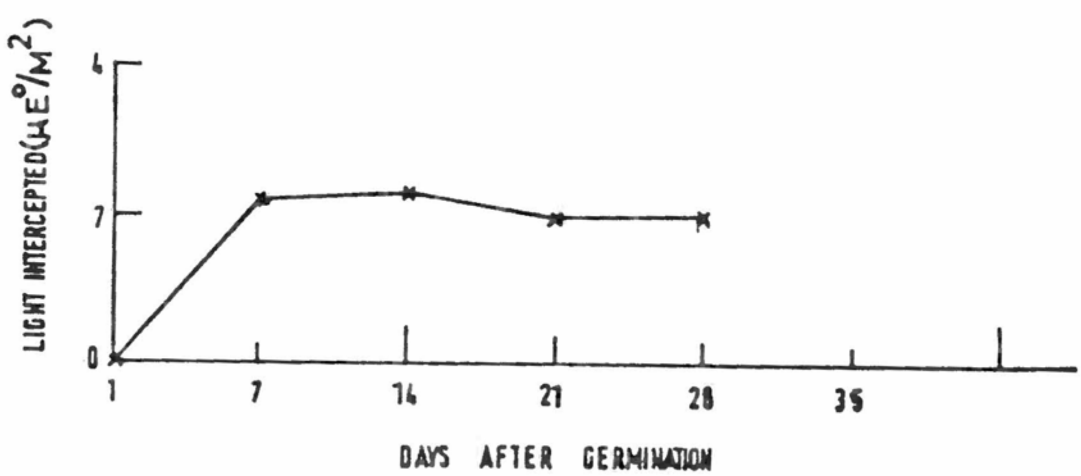


Figure 6. 2a. Light intercepted by maize in cowpea/maize intercrop(long rains 1988).



(b) short rains 1988

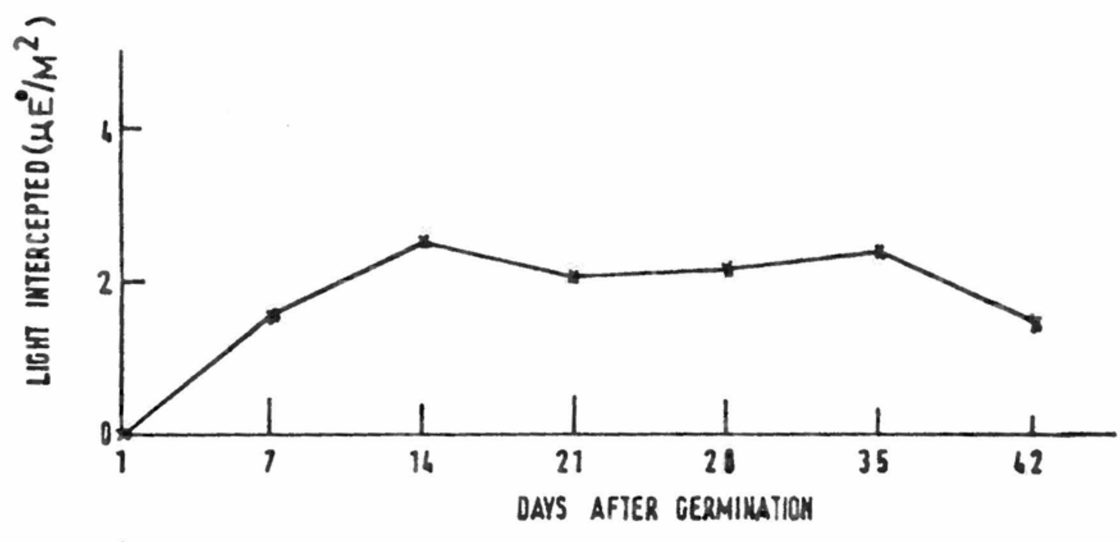


Figure 6.3. Mean temperatures and relative humidities recorded in the plots of cowpea cultivars when in pure stands and when intercropped with maize(short rains 1987).

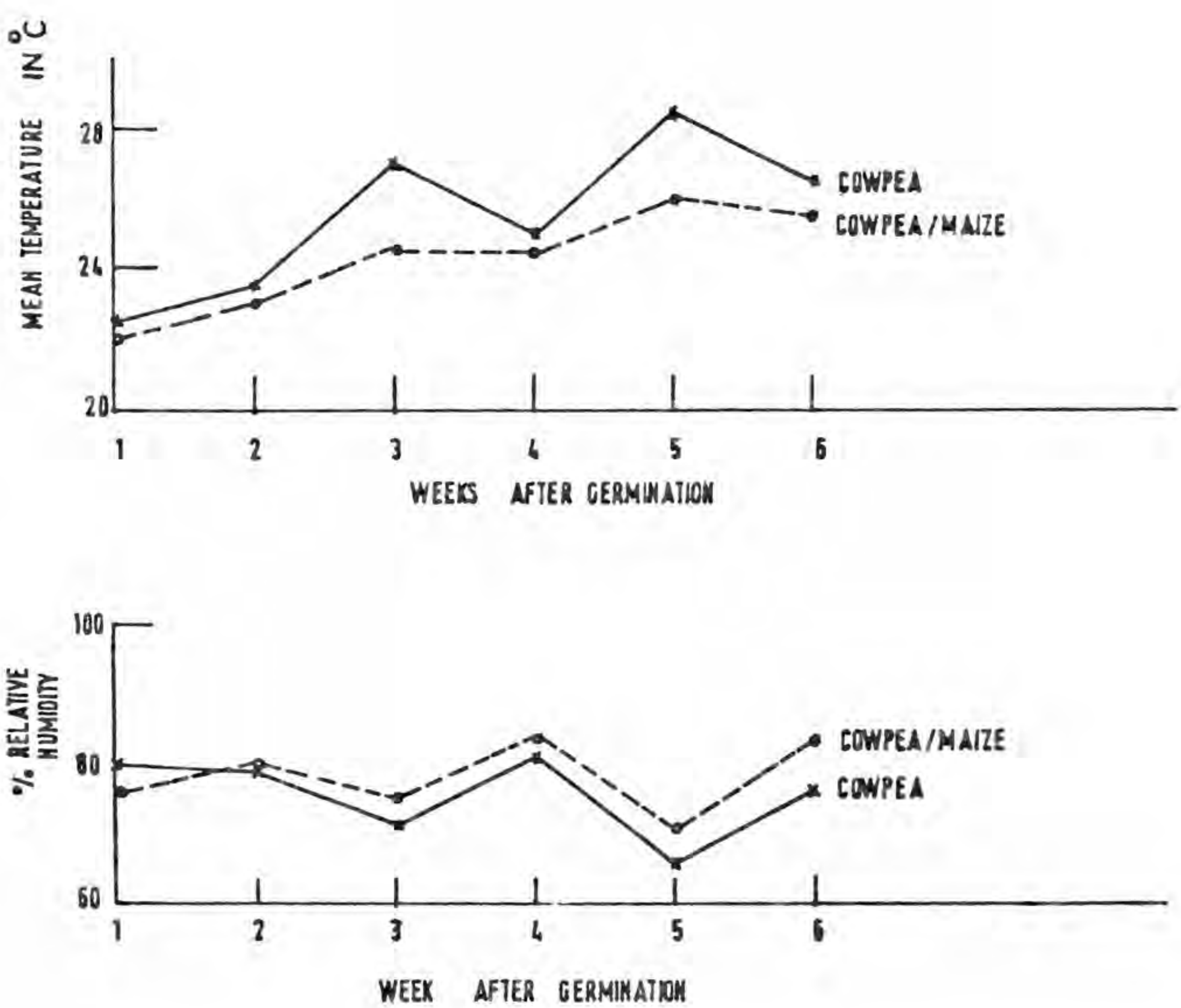


Figure 6.4. Mean temperatures and relative humidities recorded in the plots of cowpea cultivars when in pure stands and when intercropped with maize(long rains 1988).

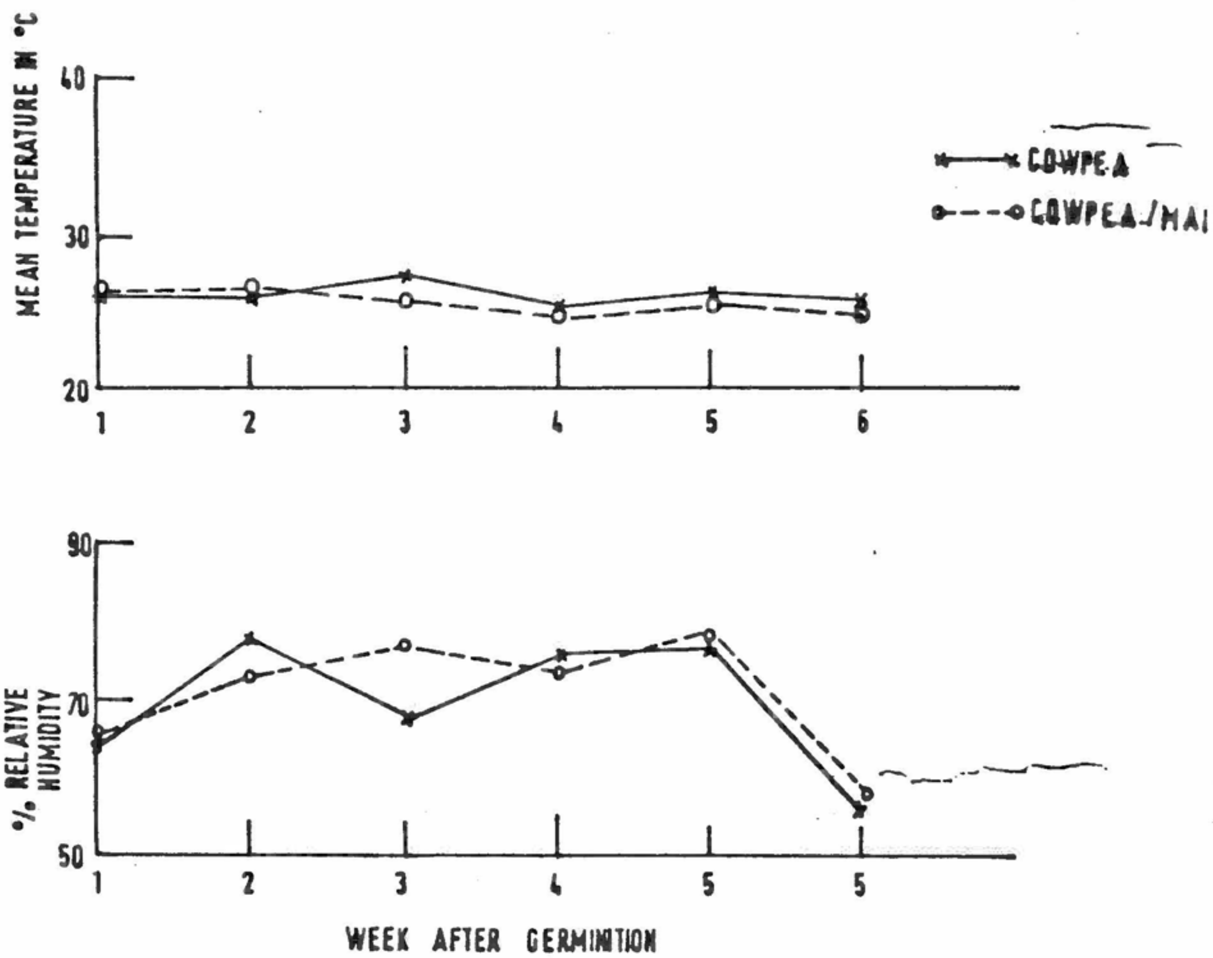


Figure 6.5. Mean temperatures and relative humidities recorded in the plots of cowpea cultivars when in pure stands and when intercropped with maize (short rains 1988).

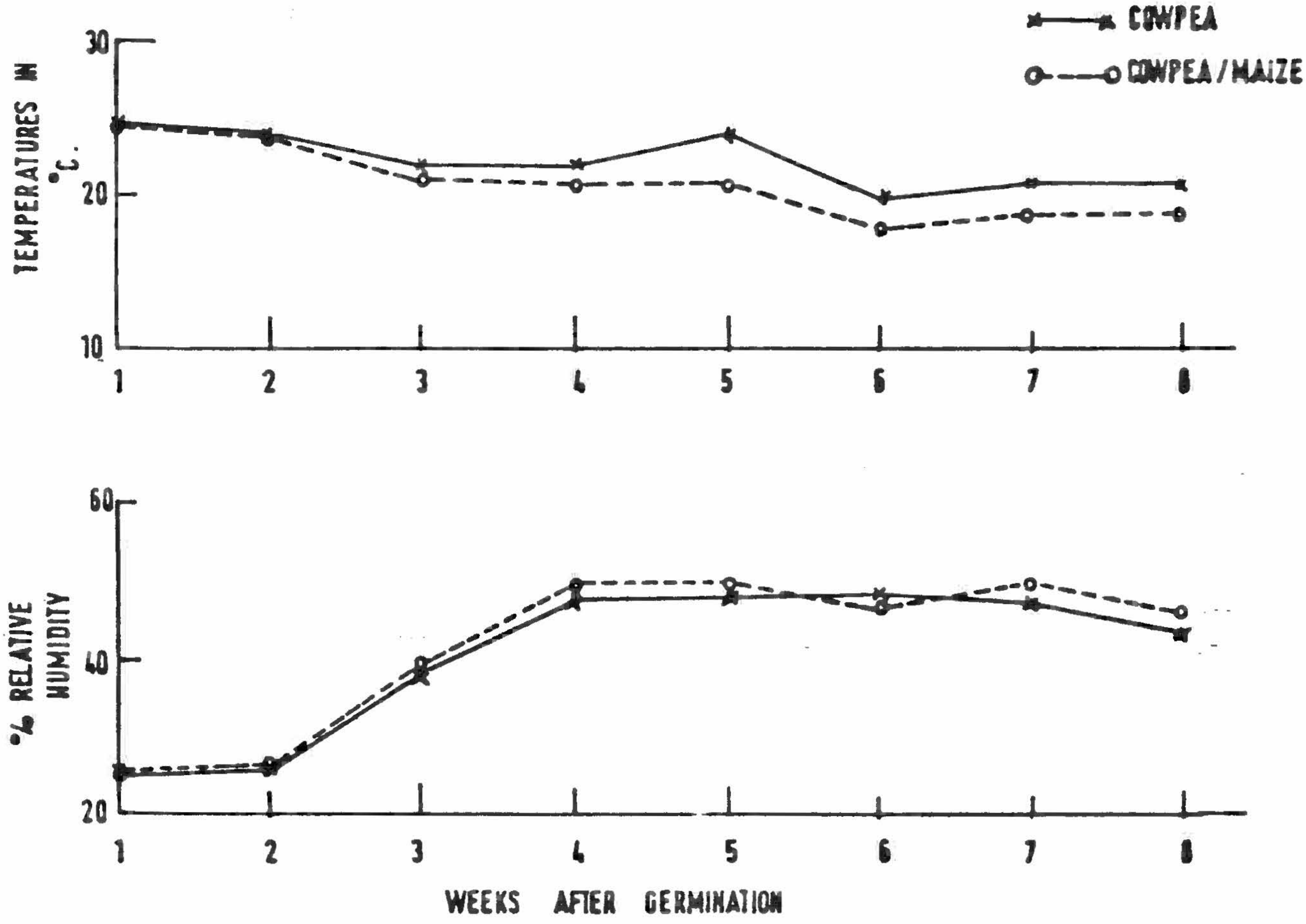


Table 6.1. Mean weekly temperatures and relative humidities taken in both pure and intercropped plots (short rains1987).

Croping system	temperatures	%RH
Pure stands	25.5 ± 0.38a	75.58 ± 0.97a
Intercropped stands	24.25 ± 0.25b	77.83 ±1.04b
CV	4.38	3.92

Means followed by the same letters in the same collumn are not significantly different at p = 0.05 (DMRT).

Table 6.2. Mean weekly temperatures and relative himidities taken in both pure and intercropped plots (long rains 1988).

Cropping system	Temperatures	%RH
Pure stands	26.14a	68.5a
Intercropped stands	25.0b	57.75b
CV	3.98	10.03

Means followed by the same letters within the same column are not significantly different at p = 0.05.(Students Newmans Kuels test).

Table 6.3. Mean weekly temperatures and relative humidities recorded frcm both pure and intercropped plots (short rains 1988).

Cropping system	Temperatures	%RH
Pure stands	22.26a	40.59a
Intecropped stands	21.07b	41.65b
CV	4.31	3.15

Means within the column followed by the same letters are not significantly different at p = 0.05 (Student Newmans Kuels test).

6 . 4 DISCUSSION.

These studies on the micro-environmental differences between the pure and intercropped plots agree with Trenbath, (1976) suggestions that the presence of a companion crop in an intercropped agro-ecosystem creates a micro-environment which differs from that found in a monoculture. It is clear from the data that in the intercropped plots there was a reduction in the photosynthetic active radiation incident on the cowpea canopy. According to Juarez et. al. ,(1982), temperatures and light intensity, together with water and nutrient availability, are the primary factors that govern plant growth and the potential competitiveness with the associated crops. The study then may have indicated that the reduction in the incident light reaching cowpea resulted in reduction of the relative growth rate of cowpea thus affecting susceptibility and resistance as indicated in section 4 . 3.

Likewise the fact that temperatures were reduced and relative humidity increased in the intercropped stands may have affected the infestation levels observed in the earlier reported experiments. This may have been due to the fact that these environmental variables affect both the amount and duration or periodicity of the crop growth. Similarly they act on the potentially attacked plants, changing their susceptibility or resistance (Trenbath, 1976).

It is a known fact that pest responses to environmental factors whether in pure stands or in mixed cropping is an important aspect in predicting when a particular pest constitutes a problem (Perrin 1977). In this particular case it was not possible to quantify the subsquent effect on colonisation of *Maruca* as the actual hour of colonisation was difficult to determine. It can therefore be concluded that studies of the effect of the micro-environment created in a cowpea maize intercrop on the responses by the pest and the crop require the use of a controlled environmental facilities in which pest and environment variables can be studied singly or in communal basis. This may help in determination as to whether a resistant cowpea variety in the unshaded environment may behave the same way when planted under shade.

CHAPTER 7

STEM BORER SPECIES COMPOSITION AND INCIDENCE ON MAIZE UNDER PURE STAND AND WHEN INTERCROPPED WITH COWPEA CULTIVARS.

7 . 1 Introduction

Studies on intercropping maize, sorghum and cowpeas by Amoako-Atta and Omolo (1983), Amoako-Atta et. al. (1983), Dissemond (1984), Omolo and Seshu Reddy (1984) and Omolo (Unpublished), have identified the cereal/legume as a good combination in terms of borer control.

Stem borers on maize are categorized as; relatively specialized stem feeders (feeding on both maize and sorghum) as opposed to generalist feeders viz.*H. armigera* which is a pest of maize, sorghum and some legumes. Studies have indicated that the distribution of these stem borers is influenced by altitude and temperatures, but information regarding the borer complex when maize is planted in association with other crops with different levels of resistance is lacking. In this regard, it was therefore decided that the role of intercropping on stem borer complex and population buildup on maize when in pure stand and when intercropped with resistant and susceptible cowpea cultivars be investigated.

7 . 2 Materials and Methods

To determine the stem borer complex and incidence, samples of the borers were taken from the field initially at two weeks intervals . This was later modified to one week intervals when it was found that infestation by the stem borers was as early as the first week of germination. Eight plants per sampling cell per week were taken from the field and the stalks were dissected to recover the borers. Larvae were then taken to the laboratory where they were identified to genus level using the crochets on the prolegs and colour. This technique had previously been used by Ogwaro (1983). Pupae from the field were also taken to the laboratory and kept in petri dishes for identification of adults after emergence (Hill, 1975). The number and species of borers present throughout the season were recorded and grouped into instars by use of body color and head capsule measurements of the larvae. The data obtained was used to determine the number of individual borer species present/plant and their occurrence over a particular season.

For studies on the parasites of stem borers, larvae and pupae collected from the field were kept in the laboratory for emergence of parasites which were later identified and recorded.

7 . 3 Yield Assessment

To assess yields of cowpea and maize within the cropping patterns, four cells were randomly selected for harvesting (Fig 2.2). Apart from the routine management practices, there was no interference to these cells until the time of harvesting. Since cowpea and maize have different growth patterns, the cowpea crop was harvested at about the 55th day and maize on the 100th day after emergence. During harvesting, the total number of plants in each crop species were recorded. For the cowpea crop, the number of pods per plant was determined from all the plants in the cell area. All the pods were threshed after sun drying for two days and the grains were weighed to determine seed yield/plant. The yields were later extrapolated to yields/ha basis for each cropping system.

For the maize crop species, the mean cob weight/plant was determined after harvesting and sun drying for several days (moisture content 12%). The maize cobs were then threshed and weighed to determine the total grain weight/plant which was later extrapolated to yields/ha for each season.

From the observed grain weights/ha for each species, Land Equivalent Ratios(LER) for each cropping pattern were determined. LER is defined as "the total land required under monoculture to give total productivity of a crop equal to one hectare of intercrop (Perrin, 1977b). This is calculated by determining the ratio of yield of a crop in mixtures to its yield in monoculture under the same management levels and with optimum monoculture populations. Ratios of all crops in the mixture are then added to give LER. Where LER is greater than one , the mixture is considered highly productive.

7. 4. RESULTS.

7. 4. 1. Stem Borer Complex And Incidence.

Results on the determination of the stem borer complex and incidence on maize when in pure stands and when interplanted with resistant and susceptible cowpea cultivars during the short rains (1987)are shown in figure 7.1 and table 7.1, and Appendices 42. The data indicated that there was a very high incidence of *C. partellus* larvae that was recorded(Fig. 7.1) during the second week of crop emergence wich thereafter reached the peak during the third week of crop emergence. The population build up then declined with little fluctuations until harvesting (Fig. 7.1). These fluctuations indicated renewed infestations in the field. During these new peaks a few 1st and 2nd larval instars were recorded. During the 2nd and 3rd week after crop emergence, intercropped stands of maize maintained a higher larval incidence than when it was as a monocrop although the differences were not distict (Fig. 7.1). Eight weeks after emergence the numbers of larvae and pupae in all the treatments stabilized with maize pure stands maitaining a slightly higher incidence of larvae/pupae (Appendix 42). Table 7.1 shows that there were no significant (p = 0.05) differences between cropping systems, although

Figure 7. 1. Incidence of *C. partellus* larvae and pupae when maize was in pure stands and when intercropped with cowpeas (short rains 1987).

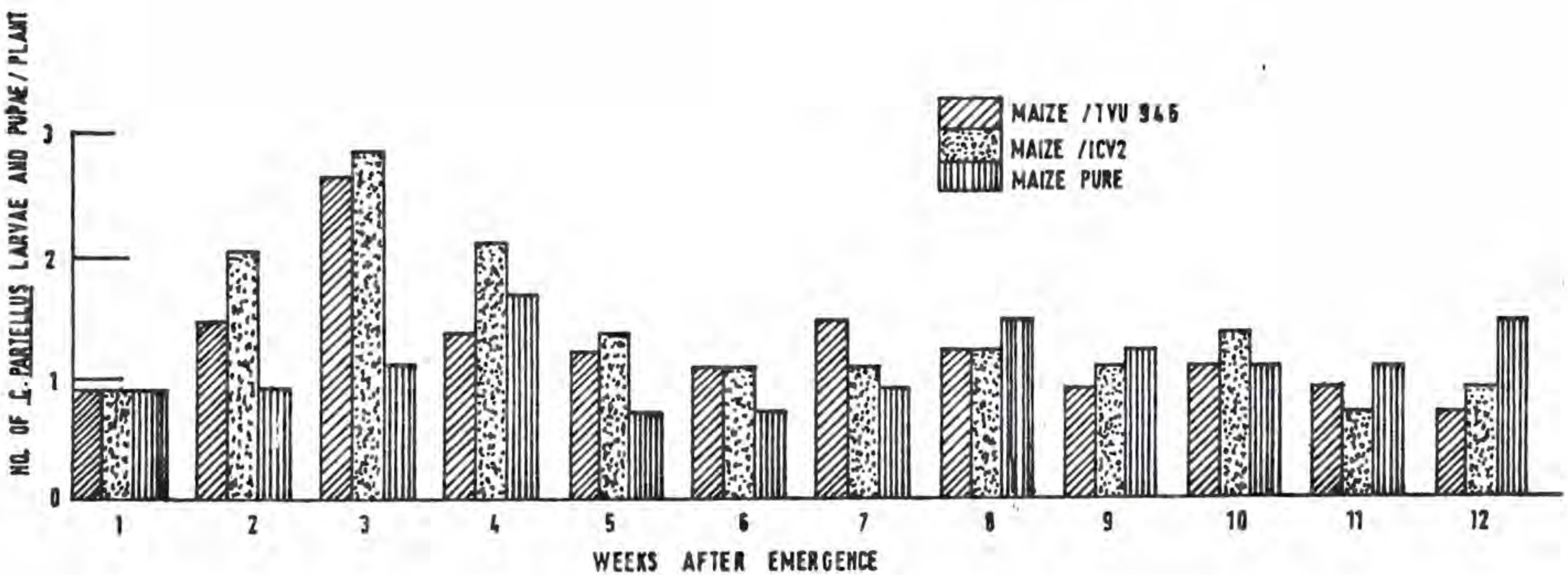


Table 7.1 Mean number of *C. partellus* larvae and pupae /plant when maize was in pure stand and when intercropped with cowpea (short rains 1987).

Cropping system	No. of larvae/pupae
Tvu 946 C/M	1.82 ± 0.13a
ICV2 c/m	2.15 ± 0.10a
Maize pure	1.53 ± 0.05a

CV = 20.17
Means followed by the same letter are not significantly different at $p = 0.05$ (SNK test).
Data transformed using sq. root (X +1).

pure stands of maize had comparativery fewer *Chilo* larvae/pupae per plant (1.53 ± 0.05) as compared to when it was intercropped with either the resistant or the susceptible cowpea cultivar (Appendix 43). Only a few of *B. fusca* larvae and pupae were observed during this season (short rains 1987) in all the cropping systems. However the incidence of *H. armigera* (Fig. 7.2) during the first seven weeks of crop emergence was extremely low(less than one borer per plant). Thereafter the population increased during the eighth and ninth week in all the plots where maize was planted as a monocrop. This was the time when maize was at silking stage. Thereafter the population declined up to harvesting (Fig. 7.2 and Appendix 44 and 45).

Figure 7.3 and table 7.3 show the incidence and the abundance of the sugarcane borer *E. saccharina* on maize. From figure 7.3,it could be noted that this pest was recorded in very low numbers during the first seven weeks in all the cropping systems. An average of one borer per plant was recorded during the eighth week after maize emergence up to harvesting. This coincided with the time that the crop attained physiological maturity, a good indication that this is a late season pest (Fig. 7.3). Tables 7.2 and 7.3 show that for both stem borers(*H. armigera* and *E. saccarina*) there were no significant ($p = 0.05$) differences in abundance between the cropping systems (Appendix 46 and 47).

Figure 7. 2. Incidence of *H. armigera* larvae when maize was in pure stands and when intercropped with cowpea(short rains 1987).

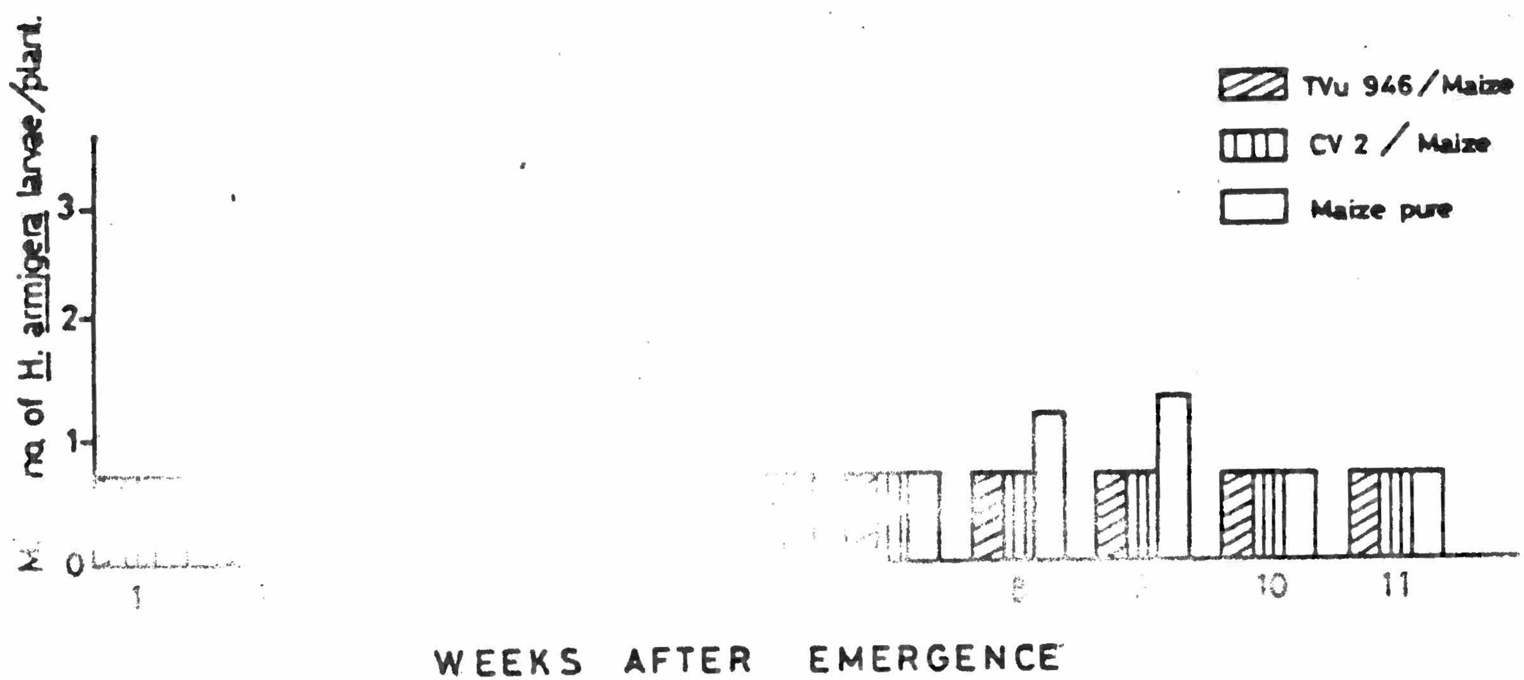


Figure 7. 3. Incindence of E. saccharina larvae and pupae when maize was in pure stands and when intercropped with cowpeas (short rains 1987).

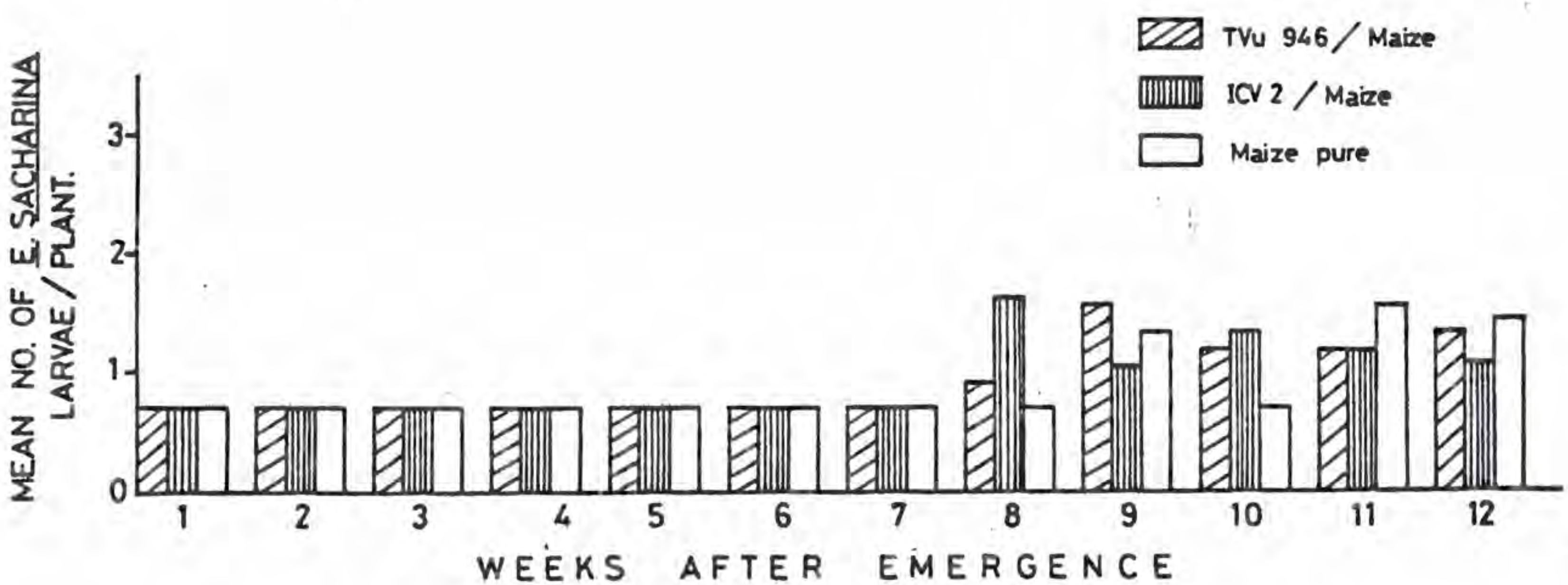


Table 7.2 Mean number of *H. armigera* larvae when maize was in pure stand and when intercropped with cowpea (short rains 1987).

Cropping system	No. of larvae
TVU 946 C/M	0.79 ± 0.05a
ICV2 C/M	0.79 ± 0.05a
Maize pure	0.93± 0.07a

CV =17.92.
Means followed by the same letter within the column are not significantly different at p = 0.05 (SNK test).
Data transformed using Sq. root(X + 1).

Table 7.3 Mean number of *E. saccharina* larvae and pupae/plant when maize was in pure stand and when intercropped with cowpea (short rains 1987).

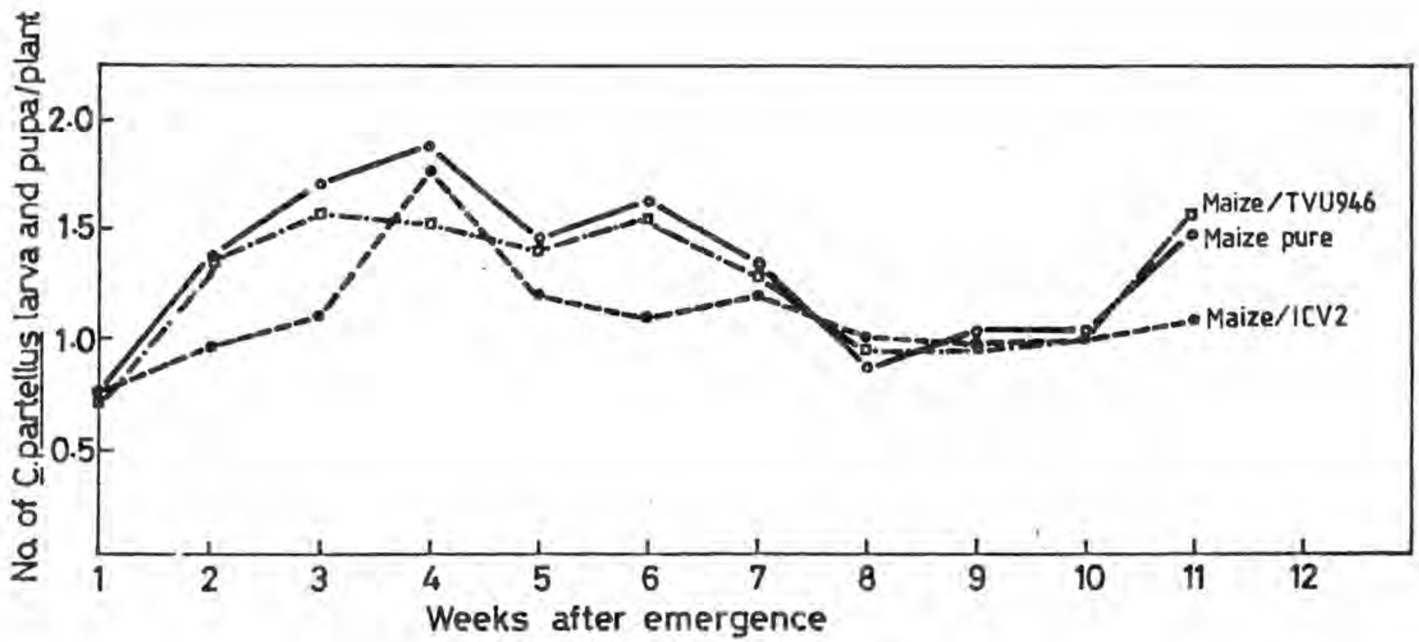
Cropping system	NO. of larvae/pupae
TVU 946 C/M	1.24 ± 0.06a
ICV2 C/M	1.22 ± 0.06a
Maize pure	1.24 ± 0.18a

CV =32.9.
Means followed by the same letter within the column are not significantly different at $p = 0.05$ (SNK test).

The incidence of stem borers observed during the long rains 1988, is shown in figure 7.4 and appendix 48. It was observed that for the *Chilo* larvae the numbers remained almost constant with an average of one larvae per plant during the first week of crop emergence. When maize was in pure stands, population of the larvae increased steadly over the period up to the fourth week after crop emergence but decreased slightly in the fifth week,rising again during the sixth week when the maize was interplanted with the two cowpea cultivars. The numbers remained low after the sixth week, but as in the previous season, the population maintained little fluctuations until the eleventh week when the numbers increased again. The second peak in week six also indicated the presence of a second infestation. This was the time when a few first and second instar *Chilo* larvae were recorded. It is also evident from the figure that maize monocrop and maize/TVU 946 combination, had a higher incidences of *Chilo* larvae/pupae from the ninth week than when maize was interplanted with cultivar ICV2 (Appendix 48b).

Treatment means indicated that maize monocrop and maize/TVU 946 combination had no significant ($p = 0.05$) differences in the number of *Chilo* larvae/pupae (Table 7.4). As in the previous season, only a few of *E. saccharina* and *H. armigera* larvae were observed in all the cropping systems at the time when the maize crop

Figure 7. 4. Incindence of C. partellus larvae and pupae when maize was in pure stands and when intercropped with cowpeas (long rains 1988).



Tables 7.4. Mean number of C. partellus larvae and pupae/plant when maize was in pure stand and when intercropped with cowpeas (Long rains 1988).

Cropping systems	No. of larvae and pupae
TVU 946 C/M	3.67 ± 0.41
ICV 2 C/M	2.89 ± 0.74
Maize pure	3.87 ± 0.69

CV = 16.67

Means transformed using Sq. Root x + 1.

was approaching physiological maturity (Appendix 49).

During the short rains of 1988, the incindence of stem borer *C. partellus* population on maize when it was in pure stands increased fast over the period up to the third week unlike in the previous season when the population peaked during the fourth week after emergence. The population then declined for sometime and then rose to reach another peak during the sixth and seventh week after crop emergence(Fig. 7.5). Thereafter the population fluctuated until the end of the season (Fig. 7.5). There were two peaks during the fourth and sixth week after crop emergence when maize was interplanted with cultivar TVu 946. Thereafter the population declined up to the harvesting time. When maize was interplanted with cultivar ICV2 the population remained stable with only small fluctuations throughout the season (Fig 7.5). As in the previous season, it is evident that maize monocrop and when it was intercropped with the resistant cultivar TVU 946 maintained higher larval population throughout the season (Apendix 50).

Treatment means as shown in table 7.5. indicated that maize as a monocrop had significantly ($p = 0.05$) more *C. partellus* larvae/pupae (4.11 ± 0.33 larvae/pupae/plant) than the other two treatments which never differed significantly ($p = 0.05$) (Appendix 51).

Similarly like in the previous season (long rains

Figure 7. 5. Incidence of *C. partellus* larvae and pupae when maize was in pure stands and when intercropped with cowpeas (short rains 1988).

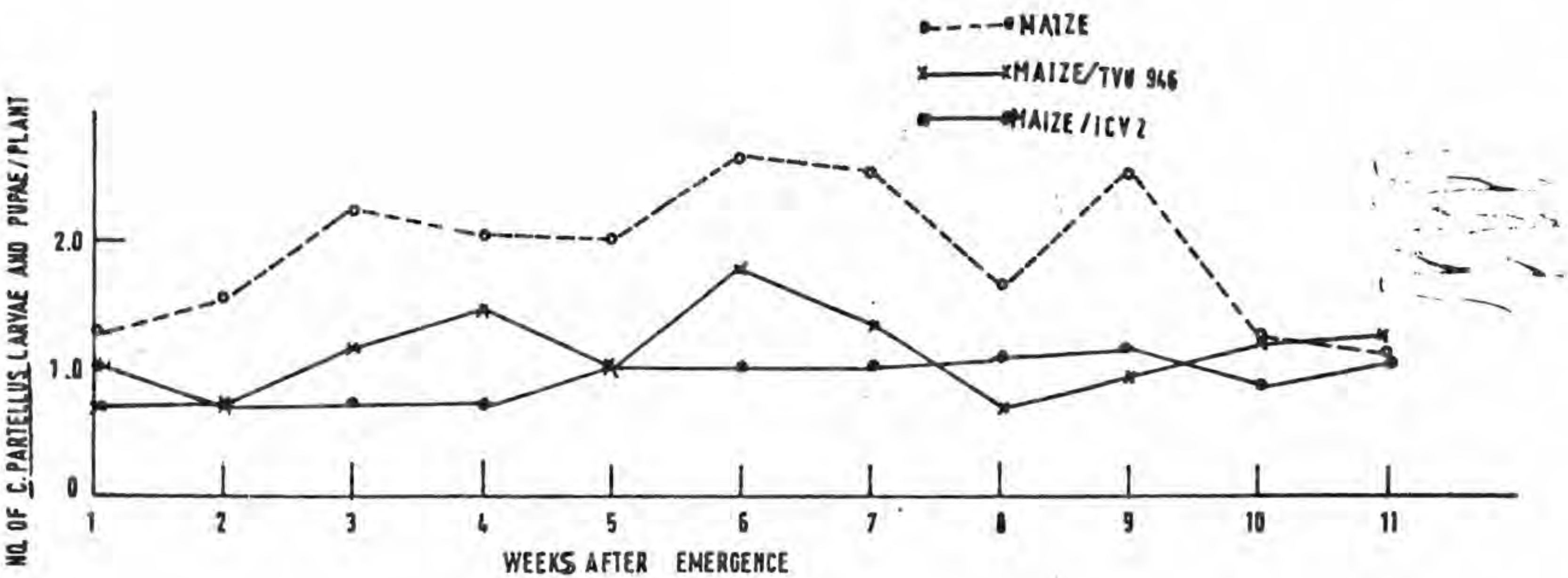


Table 7.5 Mean number of *C. partellus* larvae and pupae/plant when maize was in pure stands and when intercropped with cowpea cultivars (short rains 1988).

Cropping system	mean numbers
Maize/TVU 946	2.47 ± 0.37b
Maize/ICV2	2.07 ± 0.07b
Maize pure	4.11 ± 0.33a

CV = 19.16

Means subjected to Sq. Root x + 0.5 transformation.

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).

1988) population buildup of the other stem borers namely *H. armigera* and *E. saccharina* was fairly low in that, only a few were found scattered in all the croppig systems at the time the maize was approaching physiological maturity.

During the three cropping seasons, some natural enemies like ants (*Dorylus* sp., *Camponotus* sp. and *Pheidole* sp.) were noted as predators of *Chilo* larvae in the field, while in the laboratory *Dentichasmias* sp. and *Pediobius* sp. were noted as parasites of *Chilo* pupae.

7. 4. 2. YIELDS.

Grain yields at final harvest for both cowpea and maize are shown in tables 7.6 and 7.7 . From table 7.6 it can be seen that during the short rains of 1987, intercropped stands of both cowpea varieties (TVU 946 and ICV2) had significantly ($p = 0.05$) less grain yield per hactare (670.81 ± 65.49 and 1972.4 ± 368.01 kg/ha) compared to their respective pure stands(3697.74 ± 906.5 and 5399.10 ± 379.48 kg/ha) (Table 7.6 and Appendix 52). Although ICV2 cowpea cultivar is supposed to be susceptible to pest attack than TVU 946, it can be noted that it significantly ($p = 0.05$) outyielded all other treatments.

Table 7.6 and appendix 52 show that there were significant ($p = 0.05$) differences in pooled means between the cowpea varieties. As shown in table 7.7 there were no significant($p = 0.05$) differences in grain yields (kg/ha) between the treatments (Appendix 53). Land Equivalent Ratio when maize was intercropped with the resistant cowpea cultivar TVU 946 was found to be 1.05 while when it was intercropped with ICV2 it was found to be 1.14. This indicated that there was an overall intercropping advantage in terms of crop yields.

During the long rains of 1988, cultivar TVU 946 in pure stands outyielded all other treatments followed by cultivar ICV2 when it was interplanted with maize (2047.99 $\pm$ 379.39 and 1325.18 $\pm$ 359.41 Kg/ha respectively) (Table 7.8). Resistant cultivar TVU 946 had significantly ($p = 0.05$) the lowest grain yield per hactare when it was compared to other treatments. However there was a significant ($p = 0.05$) interaction between the cropping systems and the varieties (Appendix 54), suggesting that cropping method is an important factor in terms of yields.

The mean yields for maize in all the treatments were not significantly ($p = 0.05$) different although maize/ICV2 combination had the lowest yields per hactare than in all other treatments (Table 7.9 and Appendix 55). Results also indicated that, like in the previous season, the cowpea crop had no effect on maize yields. Also when TVU 946 was interplanted with maize

Table 7.6. Mean cowpea grain weight in kgs/plant when cowpea was in pure stand and when intercropped with maize (short rains 1987).

Cropping system	weights	pooled mean
TVU 946 C/M	670.81 ± 65.49a	2184.28 ± 1517.99a
TVU 946 pure	3697.74 ± 906.5b	
ICV2 C/M	1972.4 ± 368.01c	3685.75 ± 1718.47b
ICV2 pure	5399.10 ± 379.48d	

CV = 25.85.
Means in each column folowed by the same letter are not significantly different at p = 0.05 (SNK test).

Table 7.7. Mean maize grain yield in kgs/plant when in pure stand and when intercropped with cowpea (short rains 1987).

Cropping system	weights
TVU 946 C/M	4655.0 ± 1.29a
ICV2 C/M	4110.6 ± 5.40a
Maize pure	5350.17 ± 5.99a

CV =15 .24.

Means followed by the same letter are not significantly different at p = 0.05.(SNK test).

Table 7.8. Mean cowpea grain yield in kg/ha when cowpea was in pure stand and when intercropped with maize (Long rains 1988).

Cropping system		weights	poooled means
TVU 946	C/M	655.75 ± 355.5a	
			1351.87 ± 984.46a
TVU 946	pure	2047.99 ± 379.39b	
ICV 2	C/M	1325.18 ± 359.41b	
			1302 ± 32.09a
ICV 2	pure	1279.79 ± 270.93b	

CV = 42.72

Means within a column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).Means transformed using Log. x + 1.

the LER was 1.35 while when maize was interplanted with cultivar ICV2, LER was 1.99 indicating that both mixtures were highly productive in terms of yields.

Table 7.9. Mean maize grain weight in Kg/Ha when maize was in pure stand and when intercropped with cowpea (Long rains 1988).

Cropping system	Weights
TVU 946 /maize	1772.65 ± 540 .0a
ICV 2 / maize	1625.09 ± 745.96a
Maize pure	1723.87 ± 453.0a

CV = 26.63

Means within the column followed by the same letter are not significantly different at p = 0.05 (Student Newman Kuels test).

7 . 5 DISCUSSION

7 . 5. 1 Complex and incidence of maize stem borers.

Studies on the incidence and stem borer complex on maize in pure stands and when interplanted with resistant and susceptible cowpea cultivars, indicated that the incidence of *C. partellus* started as early as the first week of planting. Thereafter the borer population increased with plant age to reach the peak during the third and fouth week after planting in all the cropping patterns. However, the incidence of the borer during the short rain seasons was higher than during the long rain seasons. These observation are in agreement with Amoako Atta <u>et</u>. <u>al</u>. (1983) findings that the incidences of the borers are more acute during the minor season.

It appeared that except for the *C. partellus* which occurred within all the cropping systems in a definate order, none of the other borers namely *B. fusca, E. saccharina* and *H. armigera* exhibited any regularity. It was not clear as to why such a low frequency and relatively small numbers were observed. But it was assumed that these other borers are not serious pests of maize in the area where this study was conducted. However, the peak activity of the stem borer complex indicated that, the level of attack increased with the age of the crop. It was also observed that all the borers that were recorded could appear in one plant. Further more attack to plants by each borer species varied with plant age. This was due to the fact that *Chilo* sp. was the first borer that was recorded during the first week of crop emergence followed by *B. fusca* a week later. *H. armigera* and *E. saccharina* were restricted mainly to the silk, top seed and stem respectively. This time of attack by these two borers coincided with the reproductive and maturation stages of maize.

The fact that there were no significant differences in the mean number of borers per plant between different cropping patterns indicated that intercropping during the study period had no direct effect on the stem borers infestation. This was attributed to the unsynchronized growth pattern of the cowpea cultivars. In addition to this, infestation by *E. saccharina* and *H. armigera* came at a time when the cowpea crop had matured. Relatively more of *H. armigera* was recorded on maize than on cowpea. This indicated that the pest being a generalist feeder prefered to feed more on maize thereby reducing the attack on cowpea. Similar observations were reported by Way (1975) when cotton was intercropped with maize and especially when the silking of maize coincided with the boll formation on cotton.

It can therefore be concluded that *C. partellus* is the dominant stem borer on maize at M.P.F.S. and the fact that there were no significant differences in borer numbers/plant may have been due to the low incidence of *Chilo* larvae as the maize variety, Katumani composite, which was used in the experiment is known to be moderately resistant to stem borers due to its early maturing characteritcs. It can therefore be suggested that future studies should be conducted using more susceptible maize varieties.

7 . 5 . 2 YIELDS

Data on yield of both cowpea and maize for the three consecutive croping seasons indicated that except for the maize yields which were not affected by the cropping patterns, there was a drastic reduction in cowpea grain yield for both resistant and susceptible cultivars when they were planted together with maize. This indicated that the shading effect of maize in the cowpea/maize intercrop was a factor that caused yield reduction as the maize canopy intercepted sunlight thereby reducing the photosynthetic capacity of the cowpea. Ezueh and Taylor (1984) had reported similar observations on maize/bean intercrop and associated this to competition for light. Likewise the factors that influenced the pest abundance in the intercrop could have had some significant effect on the yields. This suggested that the presence of *Maruca* larvae on the crop may not have been the only factor that caused yield losses. But it may be noted that the season when the infestation of *Maruca* or thrips was high, there was a significantly higher cowpea grain yield losses .

However, in the intercropping pattern reported for the cropping seasons, there was a significant intercropping advantage in terms of Land Equivalent Ratios.

It can therefore be suggested that future studies should be undertaken to identify individualy the effect of various insects pest on yield and the interaction between pest and other physical and biological entities of cowpea/maize based agro-ecosystem.

CHAPTER 8

8 . 1 GENERAL DISCUSSION.

Cowpea/maize mixed cropping is one of the most popular agricultural system used by the small scale farmers living in semi arid and arid tropical areas. It had been indicated earlier by Nangju (1976) and Altieri et. al. (1978) that this system is characterised by a reduced pest population compared to monocropping which explains some of the reasons behind the existence of this system in the tropics. A number of mortality factors have been associated with the reduced pest incidence in an intercropped ecosystem than in monocultures, among these are, more natural enemies, crop species diversity, microclimatic gradient and chemical interactions. These factors function together thus providing an associational resistance to the target pest.

From the preceeding studies, the fact that pure stands of cowpea whether susceptible or resistant had significantly more numbers of *Maruca* larvae than in the intercropped stands was a clear indication that some of these mentioned factors were actually operating.

Differences in the relative abundance of *M. testulalis* in different cropping systems, in different seasons as demonstrated by the mean number of larvae/plant, indicated that maize as a non host plant impaired the movement of the ovipositing adults during the initial stages of the establishment thus acting as a physical barrier to the pest migration. This kind of phenomena was earlier suggested by Amoako Atta et. al. (1983) in cowpea/maize/sorghum tricrop. Differences in the mean number of larvae/plant could also be explained by the fact that the maize crop brought about a microenvironment for the cowpea crop that was different from that found in pure cultures. These were in the form of significantly low temperatures, higher relative humidities and less sunlight reaching the cowpea crop.

Lack of statistical differences in the numbers of larvae/plant between cowpea varieties(susceptible and resistant) suggested that intercropping unfavourably modified the reported resistance of variety TVU 946 to *Maruca*, and as such the variety did not have any significant effect on the infesting larvae. This conformed with the observation by Osiru (1980) that crop varieties known to be resistant when planted as a monocrop may not necessarily behave the same way when planted in association with other crops.

The observation that cultivar TVU 946 had progressively lost its resistance when planted under maize was further supported by the fact that vegetative growth of the cultivar was extensively affected by the microenvironment that was created by the maize crop and as such supported a higher larval population. This indicated that the variety was phenologically affected by intercropping as it is not well adapted to mixed cropping as opposed to ICV2 which has been grown as a mixed crop for years(Pathak and Olela, 1986). This agrees with Trenbath (1976) that, micro-environmental differences created in mixed cropping agro ecosystem act on the crop component potentially changing its susceptibility or resistance by modifying them genetically or acting directly on the attacking organism. This fact of the cultivar TVU 946 having lost its resistance when it was under maize may also be supported by Saxena's (1985) suggestion that resistance may be affected by other factors such as insect response and environmental factors. Further to that intercropping could have made cultivar TVU 946 loose some of its biophysical characters due to shading by maize or competition.

Although there were no differences in the number of *Maruca* larvae observed between varieties and cropping system, more eggs were laid on the susceptible than on the resistant cultivar and also there were more eggs on the pure stands than on intercrops. Similarly there were more eggs that were laid on the cowpea plants that were planted at the edges of all the plots where cowpea cultivars were planted together with maize, confirming that the ovipositing adults initially colonised the outer rows with the maize restricting subsquent dispersal. This agrees with Juarez et. al. (1982) suggestions that taller plants provided physical barriers which prevents some insects from penetrating the lower strata. Besides, the initial oviposition was adversely affected by the resistance traits of cultivar TVU 946, indicating that the phenological changes observed on TVU 946 under maize subsquently favoured larval establishment. This agrees with Perrin (1977a) observation that the subsquent build up of the pest is actually favoured where it finds suitable food, shelter and ovipositional requirement. Similarly plot size may have produced a significant effect on insect colonisation.

In all the intercropped plots there was a significant reduction in the amount of light that reached the cowpea canopy. This reduction of the photosynthetic active radiation incident on the cowpea canopy, inturn affected the plant height, number of pods/plant, pod length and closeness which actually forms the basis of resistance, agreeing with the work of Gardiner and Craker (1981). Reduction in the number of pods/plant hence caused a reduction in the number of damaged pods and grains. This led to the conclusion that the total number of infestable flowers or pods contribute very much to the damage that is caused by the *Maruca* larvae.

Population of the flowerbud thrips *M. sjostedti* was slightly lower in cowpea/maize intercop compared to sole cowpea crop. This decrease in the thrip numbers in all the intercropped plots was attributed to the fact that, as in the case of *Maruca*, there was a reduction in the number of infestable flowerbuds and flowers due to the reduced photosynthetic light reaching the cowpea crop. This in turn affected the number of thrips observed. Observations by Kayumbo et. al.,(1976) and Karel et. al., (1980) showed that the abundance of flowerbuds and flowers had a very great influence on thrip population. As regards the mean numbers of thrips per plant where there were no significant differences between varieties. Resistance of TVU 946 could have been lowered due to the phenological changes observed when cowpea was under maize as these phenological characters form the basis of resistance.

Data obtained during the three cropping seasons indicated that *C. partellus* was the dominant borer species. This agrees with Anon (1981) and Seshu Reddy (1983) that, *Chilo* sp. predominates the warmer areas of the country. *B. fusca* whish is reported to predominate higher altitudes (Anon, 1981) was not recorded on maize at M.P.F.S. However *H. armigera* and *E. saccharina* were recorded in very low numbers later in the season. This indicated that these borers are important during the reproductive and maturation stages of the maize crop.

However, intercropping as expected reduced the incidence of *H. armigera* although it could feed on both cowpea and maize. This is in agreement with Amoako Atta et. al. (1983) statement that this pest is a generalist feeder.

The fact that, in some cases there were no statistical differences in borer numbers between plots when maize was interplanted with cultivar TVU 946 and pure stands is explained by the fact that this particular cowpea cultivar being semi wild has a smaller plant biomass. Similarly it stays in the field for a shorter period therefore lessening its impact in an intercropped system. It can therefore be argued that *C. partellus* is the dominant stem borer on maize in the area where the study was conducted and that other borers appear in very low numbers. Duration of growth of the cowpea varieties used for intercropping is an important factor in determining the degree of borer infestation.

Maize yields obtained when it was interplanted with cowpea and when it was in pure stands did not differ significantly. On the other hand cowpea yields under maize was significantly reduced. This was attributed to the shading by maize which caused a reduction in the photosynthetic active radiation from reaching the cowpea crop, and inturn caused a reduction in growth rate. These observations are similar to those of Gardiner and Craker (1979) that bean yields in the maize/bean intercrop decreased, as a result of a reduction in the number of pods/plant.

The micro-environmental factors were the principle contributors to a great cowpea grain yield reduction despite the fact that the pests had also caused some economic losses. The overall rating of the cropping patterns expressed in terms of LER for the cropping seasons, indicated that although cowpea yields were reduced, the mixtures were highly productive . Amoako Atta and Omolo (1983) had expressed similar sentiments in a maize/sorghum/cowpea tricrop.

8 . 2 CONCLUSIONS.

Intercropping or mixed cropping system which is practiced in arid and semi-arid of tropical Africa is a basic characteristic farming system which is very popular amongst the small scale farmers, with cereal/legume combination being the most common. The review and results from the present studies indicate that this system is characterised by a reduced pest population compared to monocultures.

Results obtained from this study tends to highlight that merits of using this cropping system together with the other components of integrated pest managament such as host plant resistance which depends wholy on the environment in which the crop is planted.

During the initial colonisation and infestation by *Maruca* and thrips, there was plant age preference and also there were differences between cropping systems and cultivars. Intercropping rather than resistance of cultivar TVU 946 was a major factor that contributed to significant low numbers of pests in the plots where cowpea was planted together with maize as the ability to resist attack by these pests was greatly reduced. It was the subsquent instars of the pest that were affected by the micro-environment created by intercropping. The micro-environment differences created within the intercrop affected the resistant traits of TVU 946 as they are phenologically oriented hence modified genetically. This meant that these differences in micro environment acted directly on the cowpea plants and rendered them to be more susceptible to the pests. In this respect then, broader research programs on resistance and susceptibilty are essential with the view to identifying appropriate cultivars suitable for intercropping. It is also appparent that the shading effect by the maize on cowpea caused a reduction of flowerbuds, flowers and pods as a result of the reduction in photosynthetic active radiation incident on cowpea leading to the reduction in the infestable sites. However as would be expected, as the number of *Maruca* larvae increased, the number of pods and seeds with damage symptoms also increased.

As the magnitude and expression of genetic resistance of plant to insect is influenced by environmental factors, resistance of a crop to a particular pest when in monoculture may be lost when the crop is planted in association with other crops. In view of this, collaboration of plant breeders, agronomists and entomologists amongst others is essential in developing sustainable pest control packages. Likewise detailed study on microenvironment variables and their relationships with pests should be conducted singly or in combination in controlled environment.

In the area where these studies ware conducted, *C. partellus* was found to be the dominant stem borer,and that intercropping did affect its population buildup. Other common borers mainly *H. armigera* and *E. saccharina* are not serious borers as they are restricted to silk and the top seed respectively.

Cowpea yields were significantly reduced while maize yields were unnaffected. Otherwise when yields of the two crops were combined, there was a significantly higher crop productivity in terms of Land Equivalent Ratios.

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Appendix 1 : Incidence of *Maruca* larvae population on cowpea cultivars w..en in pure stands and when intercropped with maize (short rains 1987).

Days interval	*cropping system*			
	TVU 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
1	0.33(0.91)	0(0.71)	1.0(1.22)	0.33(0.91)
4	0.33(0.91)	0(0.71)	1.33(1.35)	0.33(0.91)
8	0(0.71)	0(0.71)	1.0(1.22)	1.67(1.47)
12	4.33(2.19)	2.0(1.58)	0.67(1.08)	2.0(1.58)
16	0.33(0.91)	0.67(1.08)	2.66(1.78)	1.0(1.22)
20	0.67(1.08)	0(0.71)	3.33(1.96)	2.0(1.58)
24	1.67(1.47)	0.33(0.91)	1.67(1.47)	1.00(1.22)

The figures in the brackets are transformed data using Sq. Root x + 0.5.

Appendix 2. Mean number of <u>Maruca</u> larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

Replicates	cropping systems			
	Tvu 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
I	0.38 (0.94)	0.5 (1.0)	0.38 (0.94)	0.75 (1.12)
II	0.38 (0.94)	0.38 (0.94)	2.0 (1.58)	1.5 (1.41)
III	2.13 (1.62)	0.13 (0.79)	2.0 (1.58)	1.88(1.54)
mean	0.96 (1.67)	0.34 (0.91)	1.46 (1.37)	1.38 (1.36)

Figures in the brackets are transformed means using Sq Root x + 0.5.

Appendix 2. cont.

Analysis of variance table

source	Df	ss	ms	F
Cropping system(a)	1	0.40	0.40	1.56
Variety(b)	1	1.72	1.72	6.64*
Blocks	2	0.24	0.12	0.46NS
a vs b	1	0.15	1.15	0.60NS
Error	6	1.55	0.26	
Total	11	4.06		

CV = 8.47 SE ± 0.51

*-- Denotes significance at p = 0.05

NS denotes not significant at p = 0.05

Appendix 3. Incidence of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Days interval	Cropping system			
	TVU 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
1	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
4	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
8	0.25 (0.87)	0.25 (0.87)	0.5 (1.0)	6.0 (2.55)
12	2.0 (1.58)	2.0 (1.58)	3.25 (1.94)	5.75 (2.50)
16	13.25 (3.71)	12.75 (3.64)	12.75 (3.64)	17.5 (4.24)
20	20.25 (4.56)	16.25 (3.57)	18.25 (4.33)	26.0 (5.15)
24	19.25 (1.50)	9.00 (3.08)	20.0 (4.53)	15.0 (3.94)
28	1.75 (1.50)	0 (0.71)	5.75 (2.50)	4.75 (2.29)

Figures in brackets are transformed data using Sq. Root x + 0.5 transformation.

Appendix 4. Mean number of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Replicates	cropping system			
	TVU 946 pure	TVU946 c/m	ICV2 pure	ICV2 c/m
I	7.3 (2.88)	3.58 (2.14)	5.67 (2.58)	5.25 (2.50)
II	3.92 (2.22)	1.83 (1.68)	4.58 (2.36)	7.08 (2.84)
III	5.58 (2.57)	5.67 (2.58)	6.00 (2.65)	6.75 (2.78)
IV	2.25 (1.80)	3.00 (2.0)	3.92 (2.22)	5.17 (2.48)
Means	4.76 (2.37)	3.52 (2.1)	5.04 (2.45)	6.06 (2.65)

Figures in the brackets are transformed means using Sq. Root x + 1 transformation.

Appendix 4 cont.

Analysis of variance table

Source	Df	ss	ms	F
Cropping system(a)	1	0.005	0.005	0.07NS
Varieties (b)	1	0.403	0.403	5.84*
Blocks	3	0.667	0.222	3.22NS
a vs b	1	0.216	0.216	3.13NS
Error	9	0.621	0.069	
Total	15	1.913		

CV = 22.81 SE ± 0.67

* -- Denotes significance at p = 0.05

NS -- Denotes not significant at p = 0.05.

Appendix 5. Incidence of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Days interval	cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
1	1.25 (1.17)	0 (0.71)	1.25 (1.17)	0.29 (0.88)
4	0 (0.71)	0.2 (0.88)	0.2 (0.88)	1.3 (1.18)
8	0 (0.71)	0.(0.71)	0.2 (0.88)	0 (0.71)
12	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)

Figures in brackets are transformed means using $\sqrt{x + 0.5}$.

Appendix 6. Mean number of *Maruca* larvae/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	2.64	2.13	4.56	2.64
II	2.13	2.13	3.00	2.13
III	3.00	2.64	2.64	2.13
Means	2.59	2.30	3.40	2.30

Data transformed using $\sqrt{x + 0.5}$

Appendix 6 cont.

Analysis of variance table.

Source	DF	SS	MS	F
Cropping system(a)	1	1.44	1.44	4.42 NS
varieties (b)	1	0.49	0.49	1.50 NS
Blocks	2	0.84	0.42	1.29 NS
a vs b	1	0.49	0.49	1.50 NS
Error	6	1.97	0.33	
Total	11	5.25		

CV = 21.63 SE ± 0.57.
NS - Denotes not significant at p = 0.05.

Appendix 7. Mean number of pods/plant at harvest when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
I	11.13 (3.41)	4.20 (2.17)	16.11 (4.08)	10.77(3.36)
II	21.77 (4.72)	3.64 (2.03)	15.13 (3.95)	13.14 (3.69)
III	17.63 (4.25)	18.22 (4.33)	9.36 (3.14)	9.09 (3.09)
means	16.84 (4.13)	8.69 (2.84)	13.53 (3.72)	11.00 (3.38)

Figures in the brackets are transformed means using Sq.Root x + 0.5 transformation.

Appendix 7 cont.

Analysis of variance table

source	Df	ss	ms	F
Cropping system(a)	1	1.98	1.98	2.67ns
Varieties(b)	1	0.01	0.01	0.002NS
Blocks	2	0.04	0.22	0.29NS
a vs b	1	0.60	0.60	0.89NS
Error	6	4.46	0.74	
Total	11	7.57		

CV = 24.52 SE ± 0.86

NS. Denotes not significant at p = 0.05.

Appendix 8. Mean number of pods/plant at harvest when cowpea cultivars were in pure stands and when intercropped with maize(long rains 1988).

Replicates	cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	14.08	3.94	4.03	2.40
II	10.49	3.75	8.17	17.33
III	18.90	9.64	10.48	5.21
IV	11.02	2.78	3.73	3.99
Means	13.62	5.03	6.60	7.23

X

Appendix 8 cont.

Analysis of variance table.

Source	Df	ss	ms	F
Cropping system(a)	1	63.44	63.44	3.75NS
Variety(b)	1	23.18	23.18	1.37NS
Blocks	3	93.84	31.28	1.85NS
a vs b	1	85.10	85.10	5.03*
Error	9	152.22	16.91	
Total	15	417.79		

CV = 50.64 NS - Not significant at p = 0.05

SE ± 2.02 * - Significant at p = 0.05

Appendix 9. Mean number of pods/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/m
I	24.7	27.6	21.8	17.8
II	19.4	11.0	22.8	15.2
III	21.8	19.2	23.3	24.4
Means	21.9	19.27	22.3	19.13

Appendix 9 cont.

Analysis of variance table.

Source	DF	SS	MS	F	
Cropping system (a)	1	25.81	25.81	1.30	NS
Variety (b)	1	0.03	0.03	0.00	NS
Blocks	2	78.53	39.27	1.98	NS
a vs b	1	0.16	0.16	0.01	NS
Error	6	118.83	19.80		
Total	11	223.37			

CV = 21.53. SE ± 0.47.
NS - Denotes not significant at p = 0.05.

Appendix 10. Mean percentage number of pods with borer damage symptoms (% of the total number of pods/plant) when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

Replicates	Cropping system							
	TVU 946 pure		TVU 946 c/m		ICV2 pure		ICV2 c/m	
I	14.43	(1.19)	21.19	(1.35)	13.77	(1.17)	19.03	(1.30)
II	16.79	(1.25)	23.18	(1.38)	17.87	(1.28)	20.21	(1.33)
III	19.68	(1.32)	3.86	(0.69)	30.88	(1.50)	23.21	(1.38)
Means	16.97	(1.25)	16.08	(1.14)	20.84	(1.32)	23.21	(1.34)

Figures in the brackets are transformed means using Log x + 1 transformation.

Appendix 10 cont.

Analysis of variance table.

Source	Df	ss	ms	F
Cropping system(a)	1	0.01	0.01	0.11NS
Varieties(b)	1	0.05	0.05	0.85NS
Blocks	2	0.02	0.01	0.13NS
a vs b	1	0.01	0.01	0.22NS
Error	6	0.35	0.06	
Total	11	0.44		

CV = 19.32 SE ± 0.24

NS Denots not significant at p = 0.05.

Appendix 11. Mean number of pods/plant with borer damage symptoms (expressed as a % of pods/plant) when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 C/M	ICV2 pure
1	87.93 (69.67)	54.82 (47.77)	51.36 (45.78)	68.75(56.01)
II	43.76 (41.42)	65.87 (54.25)	52.63 (46.51)	43.76 (41.42)
III	43.92 (41.51)	51.66 (45.95)	49.53 (44.73)	56.81 (48.91)
IV	56.17 (48.54)	39.21 (38.77)	48.26 (44.00)	65.16 (53.82)
Means	(50.29)	(46.69)	(45.26)	(50.04)

Figures in the brackets are transformed means using Arcsine transformation.

Appendix 11 cont.

Analysis of variance table

Source	Df	ss	Ms	F
Cropping system(a)	1	70.31	70.31	1.17 NS
Variety (b)	1	2.81	2.81	0.05 NS
Blocks	3	244.4	81.48	1.36Ns
a vs b	1	1.40	1.40	0.02 NS
Error	9	540.78	60.09	

CV = 16.13. SE ± 2.78.
NS - Not significant at p = 0.05.

Appendix 12 Relationship between the number of *Maruca* larvae/plant and pods with damage symptoms (short rains 1987).

Maruca larvae/plant	% No. of damaged pods
0.94	22.33
0.94	24.18
1.62	26.33
1.00	27.41
0.94	28.78
0.79	11.33
0.94	21.78
1.58	25.01
1.58	33.76
1.12	25.85
1.41	26.72
1.54	28.80

Appendix 13 Relationship between the number of *Maruca* larvae/plant and pods with damage symptoms (long rains 1988).

Maruca larvae/plant	% No. of damaged pods
2.88	69.67
2.22	41.42
2.57	41.51
1.80	48.54
2.14	47.77
1.68	54.25
2.58	45.95
2.00	38.77
2.58	56.01
2.36	41.42
2.65	48.91
2.22	53.82
2.50	45.78
2.84	46.51
2.76	44.73
2.48	44.00

Appendix 14 Mean weight in grams/plant of damaged cowpea grains when in pure stand and when intercropped with maize (long rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 C/M	ICV2 pure
I	0.66	0.36	0.50	0.37
II	0.43	0.33	0.44	0.53
III	0.63	0.48	0.47	0.59
IV	0.33	0.32	0.52	0.64
Means	0.51	0.37	0.48	0.53

Appendix 14 cont.

Analysis of variance table.

Source	DF	SS	MS	F	
Cropping system(a)	1	0.03	0.03	2.80	NS
Varieties (b)	1	0.02	0.02	1.28	NS
Blocks	3	0.02	0.01	0.68	NS
a vs b	1	0.01	0.01	0.74	NS
Error	9	0.11	0.74		
Total	15	0.19			

CV = 23.34 SE ± 0.11
NS - Not significant at p = 0.05.

Appendix 15. Incidence of flowerbud thrips population/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

Days interval	cropping system			
	Tvu 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
1	1.67 (1.47)	3.51 (2.00)	3.45 (1.99)	2.0 (1.98)
4	4.88 (2.32)	4.29(2.19)	5.92 (2.53)	5.96 (2.54)
8	6.42 (2.63)	7.59 (2.84)	4.96 (2.34)	6.04 (2.56)
12	13.75 (3.77)	7.92 (2.90)	9.51 (3.16)	11.04 (3.39)
16	5.29 (2.41)	2.05 (1.64)	8.51 (3.00)	8.0 (2.92)
20	2.24 (1.66)	1.00 (1.22)	8.92 (3.07)	6.41 (2.63)

Figures in the brackets are transformed means using Sq Root x + 0.5 transformation.

Appendix 16. Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987).

Replicates	cropping system			
	TVU 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
I	30.01 (5.52)	32.01 (5.70)	35.38(5.99)	45.38 (6.77)
II	30.38 (5.56)	27.0 (5.24)	42.38 (6.55)	35.5 (6.00)
III	44.38 (6.69)	25.0 (5.05)	46.01 (6.82)	37.51 (6.17)
mean	34.92 (5.92)	28.00 (5.33)	41.25 (6.45)	39.46 (6.31)

Figures in brackets are means transformed using Sq Root x + 0.5 transformation

Appendix 16 cont.

Analysis of variance table

Source	Df	ss	ms	F
cropping system(a)	1	0.40	0.40	1.56Ns
Variety(b)	1	1.71	1.71	6.64*
blocks	2	0.24	0.12	0.40NS
a vs b	1	0.15	0.15	0.60NS
error	6	1.55	0.25	
Total	11	4.06		

CV = 8.47 SE ± 0.61

* Denotes significance at p = 0.05

NS denotes non significance at p = 0.05

Appendix 17. Incidence of flowerbud thrips when cowpea cultivars were in pure stands and when intercropped with maize (Long rains 1988).

Days interval	cropping system			
	TVU 946 pure	TVU946 C/M	ICV2 pure	ICV2 C/M
1	0.63	0.08	0.33	0.88
4	1.63	1.67	0.75	1.25
8	1.81	1.89	1.58	1.48
12	1.83	1.52	2.25	3.67
16	2.17	2.00	2.54	1.99
20	1.15	0.92	1.89	0.85

Figures transformed using $\sqrt{x+0.5}$ transformation

Appendix 18 Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (long rains 1988).

Replicates	cropping system			
	TVU 946 Pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	10.0 (3.24)	8.7 (3.04)	11.25 (3.43)	1.58 (1.44)
II	5.67 (2.48)	7.92 (2.90)	7.75 (2.87)	10.17 (3.27)
III	13.5 (3.74)	10.33 (3.29)	9.33 (3.14)	12.5 (3.61)
IV	6.25 (2.59)	5.33 (2.41)	5.08 (2.36)	12.83 (3.65)
Means	(2.89)	(2.91)	(2.95)	(2.96)

Figures in the brackets are transformed means using $\sqrt{x+0.5}$ transformation.

Appendix 18 cont.

Analysis of variance table

Source	Df	ss	ms	F
Cropping system(a)	1	0.004	0.004	0.01NS
Variety(b)	1	0.001	0.001	0.002NS
Blocks	3	1.257	0.419	0.92 NS
a vs b	1	0.02	0.02	0.05 NS
Error	9	4.119	0.457	
Total	15	5.401		

CV = 22.81 SE ± 0.68 NS- Not significant at P = 0.05

Appendix 19. Incidence of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Days interval	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
1	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)
7	1.66 (1.46)	2.67 (1.78)	1.3 (1.34)	0.7(1.09)
14	20.7 (4.60)	4.73 (2.29)	22.57(4.80)	17.76 (4.27)
21	0 (0.71)	0 (0.71)	0 (0.71)	0 (0.71)

Figures in the brackets are transformed data using $\sqrt{x}$ +0.5.

Appendix 20. Mean number of flowerbud thrips/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	13.6(1.16)	11.2 (1.08)	30.4(1.49)	18.6(1.29)
II	29.3 (1.48)	4.40 (0.73)	9.90 (1.04)	11.0 (1.08)
III	24.2 (1.40)	6.60 (0.88)	31.3 (1.51)	25.8 (1.43)
Means	(1.35)	(0.89)	(1.35)	(1.26)

Figures in the brackets are transformed means using $\sqrt{x + 1}$ transformation.

Appendix 21a. Analysis of variance for the mean number of ***Maruca*** larvae/plant sampled from the fourth week after emergence of cowpea cultivars when in pure stands and when intercropped with maize (short rains 1987).

Source	DF	SS	MS	F
Sampling interval	6	1.49	0.25	1.88 NS
Cropping system	3	1.01	0.34	2.53 NS
Error	18	2.39	0.13	
Total	27	4.89		

NS - Denotes not significant at $p = 0.05$

Appendix 21b. Long rains 1988.

Source	DF	SS	MS	F
Sampling interval	7	64.18	9.17	47.23*
Cropping system	3	3.37	1.12	5.78*
Error	21	4.08	0.19	
Total	31	71.62		

* - Denotes significance at p = 0.05.

Appendix 21c. Short rains 1988.

Source	DF	SS	MS	F
Sampling interval	3	0.20	0.07	2.54 NS
Cropping system	3	0.05	0.02	0.69 NS
Error	9	0.24	0.03	
Total	15	0.49		

NS - Denotes not significant at p = 0.05.

Appendix 22. Mean plant height in Cm/plant at 40th day after cowpea emergence when the cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	17.3	14.3	33.0	51.95
II	20.35	18.55	42.95	47.25
III	24.1	16.35	43.87	42.25
Means	20.58	18.07	39.94	47.15

Appendix 22 cont.

Analysis of variance Table.

Source	DF	SS	MS	F
Cropping system (a)	1	16.52	16.52	0.71 NS
Variety (b)	1	1759.82	1759.82	75.29*
Blocks	2	7.38	3.69	0.16 NS
a vs b	1	70.95	70.95	3.03 NS
Error	6	146.25	23.37	
Total	11	1994.93		

CV = 15.38. SE $\pm$ 0.93.

* - Denotes significance at p = 0.05.
NS - Denotes not significant at p = 0.05.

Appendix 23. Mean number of branches/plant at 40 days after emergence when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	9.4	8.4	11.7	5.4
II	11.7	5.9	7.1	5.3
III	10.5	7.5	8.7	6.3
Means	7.27	7.6	9.17	5.67

Appendix 23 cont.

Analysis of variance table.

Source	DF	SS	MS	F
Cropping system(a)	1	0.04	0.04	0.02 NS
Variety (b)	1	6.60	6.60	2.77 NS
Blocks	2	3.05	1.52	0.64 NS
a vs b	1	34.34	34.34	14.39*
Error	6	14.32	2.39	
Total	11	58.34		

CV = 18.93 SE ± 0.75.

* - Denotes significance at p = 0.05.
NS - Denotes not significant at p = 0.05.

Appendix 24. Mean pod length in Cm/plant at 40 days after emergence of cowpea cultivars when in pure stands and intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	7.15	9.25	10.35	10.01
II	7.50	17.6	13.0	9.2
III	10.9	10.2	14.1	12.3
Means	12.43	8.52	12.48	10.05

Appendix 24 cont.

Analysis of variance table.

Source	Df	SS	Ms	F
Cropping Systems(a)	1	25.35	25.34	3.45 NS
Varieties (b)	1	3.37	3.37	0.46 NS
Blocks	2	18.87	9.44	1.28 NS
a vs b	1	2.58	2.58	0.35 NS
Error	6	44.11	7.35	
Total	11	94.27		

CV = 24.73 SE ± 0.53.
NS - Denotes not significant at p = 0.05.

Appendix 25. Mean peduncle length in Cm/plant at 40th day after cowpea emergence when the cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	24.2	31.6	19.1	29.9
II	21.7	34.5	27.8	26.1
III	30.6	40.0	26.8	28.4
Means	25.5	35.37	25.5	28.13

Appendix 25 cont.

Analysis of variance table.

source	DF	SS	MS	F
Cropping system(a)	1	135.34	135.34	11.35*
Variety (b)	1	50.02	50.02	4.19 NS
Blocks	2	59.63	29.81	2.50 NS
a vs b	1	29.77	29.77	2.50 NS
Error	6	71.57	11.92	
Total	11	346.33		

CV = 12.16 SE ± 0.79

* - denotes significance at p = 0.05
NS - denotes not significant at p = 0.05.

Appendix 26. Mean number ofcowpea leaves/plant at 40 days after after emergence when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	29.8	36.0	40.3	18.1
II	18.1	10.6	27.6	17.7
III	25.5	20.8	30.3	18.7
Means	24.5	22.5	32.73	18.17

Appendix 26. cont.

Analysis of variance table

Source	DF	SS	MS	F
Cropping system (a)	1	118.44	118.44	4.19 NS
Variety (b)	1	11.80	11.80	0.42 NS
Blocks	2	317.41	158.71	5.62*
a vs b	1	205.84	205.84	7.29*
Error	6	169.42	28.24	
Total	11	822.91		

CV = 21.73

SE ± 5.31

* - Denotes significance at P = 0.05
NS - Denotes Non Significance at p = 0.05.

Appendix 27. Mean number of stems/row with *Maruca* larvae damage symptoms when cowpea cultivars were in pure stands and when intercropped with maize (screen cage).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	5.13	5.03	5.68	4.70
II	4.16	4.41	3.00	6.25
III	2.13	3.77	2.64	5.28
IV	5.18	4.33	6.88	8.10
Means	4.59	3.93	5.78	4.86

Appendix 27 cont.

Analysis of variance table.

Source	DF	SS	MS	F
Cropping system (a)	1	3.12	3.12	2.52 NS
Variety (b)	1	4.39	4.39	3.55 NS
Blocks	3	15.16	5.05	4.08*
a vs b	1	1.68	1.68	1.36 NS
Error	9	11.15	1.23	
Total	15	35.52		

CV = 23.23. SE $\pm$ 0.68

* - Denotes significance at p = 0.05
NS - denotes not significant at p = 0.05.

Appendix 29. Mean number of pods/row with *Maruca* damage symptoms at harvest when cowpea cultivars were in pure stands and when intercropped with maize (screen cage).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	48.82 (7.02)	41.58 (6.49)	63.75(8.02)	43.64(6.64)
II	43.28 (6.62)	0 (0.71)	3.69 (2.05)	0 (0.71)
III	43.26 (6.62)	41.04 (6.45)	46.51 (6.86)	50.47 (7.14)
IV	48.08 (6.96)	0 (0.71)	55.74 (7.49)	38.46 (6.24)
Means	(6.81)	(3.59)	(6.11)	(5.18)

Figures in the bracket are transformed means using $\sqrt{x + 0.5}$ Transformation.

Appendix 29 cont.

Analysis of Variance table.

Source	DF	SS	MS	F
Cropping system (a)	1	16.75	16.75	4.74 NS
Variety (b)	1	0.72	0.72	0.20 NS
Blocks	3	50.92	16.97	4.80*
a vs b	1	5.46	5.46	1.54 NS
Error	9	31.83	3.53	
Total	15	105.67		

CV = 34.77. SE ± 0.69

* - Denotes significance at p = 0.05
NS - Denotes not significant at p = 0.05.

Appendix 30a. Abundance of *Maruca* eggs/plant on cowpea cultivars when planted in pure stands and intercropped with maize : (short rains 1987).

Days interval	Cropping system			
	TVU 946 c/m	TVU 946 pure	ICV2 c/m	ICV2 pure
1	0 (0.71)	0 (0.71)	0.29 (0.89)	0.71 (1.10)
4	0 (0.71)	0 (0.71)	0.09 (0.77)	0.12 (0.79)
8	0.04 (0.73)	0.08 (0.76)	0 (0.71)	0.17 (0.82)
12	0.08 (0.76)	0.12 (0.79)	0.25 (0.87)	0 (0.71)
16	19.59 (4.48)	31.23 (5.63)	58.51 (7.68)	53.96 (7.38)
20	24.71 (5.02)	51.96 (7.24)	60.63 (7.82)	54.84 (7.44)
24	27.25 (5.27)	51.13 (7.18)	61.0 (7.84)	64.79 (8.08)
28	24.17 (4.97)	46.47 (6.85)	54.33 (7.40)	63.13 (7.98)
32	11.29 (3.43)	27.33 (5.28)	37.13 (6.13)	38.88 (6.28)
36	3.76 (2.06)	10.88 (3.37)	19.84 (4.51)	22.17 (4.76)

Figures in the brackets are transformed data using Sq.Root x + 0.5

Appendix 30b Abundance of *Maruca* eggs/plant when cowpea cultivars were in pire stands and .. : intercropped with maize (long rains 1988).

Days interval	Cropping system			
	TVU 946 C/M	TVU 946 pure	ICV2 C/M	ICV2 C/M
1	0 (0.71)	0.08 (0.76)	0 (0.71)	0.13 (0.79)
4	0.05 (0.74)	0.29 (0.89)	0.35(0.92)	0.61 (1.05)
8	0.54 (1.02)	0.58 (1.04)	1.58 (1.44)	1.35 (1.36)
12	1.10 (1.26)	1.15 (1.28)	2.63 (1.77)	2.25 (1.66)
16	1.15 (1.28)	2.63 (1.77)	2.98 (1.88)	4.98 (2.34)

Figures in the brackets are transformed means using $\sqrt{x + 0.5}$.

Appendix 30a. Abundance of *Maruca* eggs/plant when cowpea cultivars were in pure stands and intercropped with maize (short rains 1988).

Days interval	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
1	2.00	1.81	2.81	2.66
4	1.34	1.05	1.82	1.29
8	1.17	1.57	2.43	1.91
12	4.52	2.15	6.36	5.19

Data transformed using $\sqrt{x+0.5}$ transfomation.

Appendix 31a. Analysis of variance for the mean number of *Maruca* eggs/plant sampled from the third week after emergence when cowpea cultivars were in pure stands and when intercropped with maize(short rains 1987).

Source	DF	SS	MS	F
Sampling interval	9	296.04	32.89	71.34*
Cropping system	3	18.99	6.33	1373*
Error	27	12.45	0.46	
Total	39	372.48		

*- Denotes significance at p = 0.05

Appenndix 31b. Long rains 1988.

Source	DF	SS	MS	F
Sampling interval	4	3.04	0.76	23.58*
Cropping system	3	0.58	0.19	5.98*
Error	12	0.39	0.03	
Total	19	4.01		

* - Denotes significance at p = 0.05.

Appendix 31c. Short rains 1988.

Source	DF	SS	MS	F
Sampling interval	3	6.38	2.13	1.84 NS
Cropping system	3	23.47	7.82	6.76*
Error	9	10.41	1.16	
Total	15	40.26		

* - Denotes significance at p = 0.05
NS - denotes not significant at p = 0.05.

Appendix 32. Mean number of *Maruca* eggs/plant when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 pure	ICV2 C/M
I	7.41	8.64	12.61	11.74
II	11.83	5.45	14.88	12.27
III	7.11	6.46	11.89	9.41
Means	8.78	6.83	13.12	11.14

Appendix 32 cont.

Analysis of variance table

Source	DF	SS	MS	F
Cropping system(a)	1	11.64	11.64	4.07NS
Variety (b)	1	56.16	56.16	19.63*
Blocks	2	11.67	5.83	2.04 NS
a vs b	1	0.001	0.001	0.0001NS
Error	6	17.17	2.86	
Total	11	96.64		

CV = 16.96. SE ± 1.69.

* - Denotes significance at p = 0.05.
NS - Denotes not significant at p = 0.05.

Appendix 34. Abundance of *Maruca* eggs/plant at the edges and centres of cowpea plots when cultivars were in pure stands and when intercropped with maize (screen cage).

Days interval	Cropping system							
	TVU 946 pure		TVU 946 C/M		ICV2 pure		ICV2 C/M	
	Edge	center	Edge	Centre	Edge	Centre	Edge	Centre
1	0.72	0.69	0.62	0.76	0.90	0.84	1.29	1.27
2	0.78	0.98	0.81	0.79	0.98	0.93	1.27	1.17
3	0.78	1.19	0.94	1.15	1.12	0.93	1.02	1.18
4	0.48	0.54	1.09	1.02	1.11	1.18	1.48	1.38
5	0.74	0.76	1.06	0.98	1.16	1.18	1.37	1.37
6	1.62	1.56	2.18	2.11	2.01	2.15	2.31	2.28
7	2.01	1.97	2.26	2.23	2.17	2.19	2.28	2.09
8	1.93	1.91	1.71	1.59	1.81	1.99	2.09	1.99

Data transformed using Log x + 1 Transformation.

Appendix 35. Mean number of *Maruca* eggs/plant at the edge and centres of cowpea plots when the cultivars were in pure stands and when intercropped with maize (screen cage).

Replicates	Cropping system							
	TVU 946 C/M		TVU 946 pure		ICV2 pure		ICV2 C/M	
	Edge	centre	edge	centre	edge	centre	edge	centre
I	1.59	1.54	1.52	1.49	1.47	1.39	1.53	1.63
II	0.63	0.91	1.49	1.42	1.57	1.51	1.07	1.02
III	0.70	0.67	1.23	1.17	1.67	1.32	1.20	1.09
IV	0.48	0.67	0.89	0.85	1.12	1.10	1.21	1.32
Means	0.85	0.94	1.28	1.23	1.46	1.33	1.25	1.27

Data transformed using log x + 1 transformation.

Appendix 35 cont.

Analysis of variance table.

Source	DF	SS	MS	F
Cropping system (a)	1	0.48	0.48	10.59*
Variety (b)	1	0.49	0.49	10.70*
sample (c)	1	0.001	0.001	0.04 NS
Blocks	3	1.34	0.45	9.78*
a vs b	1	0.09	0.09	2.15 NS
b vs c	1	0.04	0.04	0.94 Ns
Error	23	1.05	0.05	
Total	31	3.49		

CV = 17.75. SE ± 0.70.

* - Denotes significance at p = 0.05.
NS - Denotes not significant at p = 0.05.

Appendix 39 Mean temperatures, % relative humidity and solar radiation in both pure and intercropped stands (short rains 1987).

weeks after emergence	parameters					
	tempatures(°C)		% RH		solar in Angs./m2	
	pure	intercrop	pure	intercrop	pure	intercrop
1	25	25	63	63	817	817
2	22.5	22	80	76	817	817
3	23.5	23	78	80	280	112.5
4	27	24.5	71.5	75.5	930	200
5	25	24.5	81	84	666.3	197.3
6	28.5	26	66	67.5	1132	512
7	26.5	25.5	76	84	618.5	460
Means	25.5	24.25	75.58	77.83	740.6	383.13

Appendix 41. Mean temperatures and % relative humidities from both pure and intercropped cowpea stands (short rains 1988).

Weeks after emergence	Parameters			
	Temperatures (°C)		% Relative humidity	
	pure	intercropp	pure	intercropp
1	24.93	24.93	23.71	23.71
2	24.08	24.09	25.71	25.72
3	21.77	21.27	38.38	39.11
4	21.56	21.25	47.61	50.13
5	24.14	20.71	47.21	50.25
6	19.63	18.38	49.09	47.46
7	20.93	18.61	48.68	50.46
8	21.07	19.28	44.32	46.32
Means	22.26	21.07	40.59	41.65

Appendix 42. Incidence of *C. partellus* larvae or pupae/plant when maize was in pure stands and when intercropped with cowpea cultivars (short rains 1987).

Week after germination	cropping system		
	maize/TVU 946	maize/ICV2	maize pure
1	0.33 (0.91)	0.33 (0.91)	0.33 (0.91)
2	1.67 (1.47)	3.67 (2.04)	0.33 (0.91)
3	6.67 (2.68)	7.67 (2.86)	0.67 (1.08)
4	1.33 (1.35)	4.00 (2.12)	2.33 (1.08)
5	1.00 (1.22)	1.33 (1.35)	0 (0.71)
6	0.67 (1.08)	0.67 (1.08)	0 (0.71)
7	1.67 (1.47)	0.67 (1.08)	0.33 (0.91)
8	1.00 (1.22)	1.00 (1.22)	1.67 (1.47)
9	0.33 (0.91)	0.67 (1.08)	1.00 (1.22)
10	0.67 (1.08)	1.33 (1.35)	0.67 (1.08)
11	0.33 (0.91)	0 (0.71)	0.66 (1.08)
12	0 (0.71)	0.33 (0.91)	1.66 (1.47)

Figures in the brackets are transformed data using Sq. Root x + 0.5 transformation.

Appendix 43. Mean number of *C. partellus* larvae or pupae/plant when maize was in pure stands and when intercropped with cowpea cultivars (short rains 1987).

Replicates	cropping system		
	maize/TVU 946	maize/ICV2	maize pure
I	3.20 (1.92)	4.2 (2.17)	1.80 (1.52)
II	4.2 (2.17)	2.8 (1.82)	2.4 (1.70)
III	1.4 (1.38)	5.6 (2.47)	1.4 (1.38)
Means	2.93 (1.82)	4.2 (2.15)	1.87 (1.53)

Figures in the brackets are transformed means using Sq. Root x + 1 transformation.

Appendix 43 cont.

Analysis of Variance table

source	Df	ss	ms	F
Replicates	2	3.69	1.84	2.82NS
Treatments	2	2.87	1.44	2.20NS
Error	4	2.61	0.65	
Total	8	9.17		

CV = 20.17 SE ± 0.37

NS - Denotes not significant at p = 0.05

Appendix 44. Incidence of *H. armigera* larvae/plant when maize was in pure stands and when intercropped with cowpea (short rains 1987)

Weeks after emergence	cropping system		
	maize/TVU 946	maize/ICV2	maize pure
1	0 (0.71)	0 (0.71)	0 (0.71)
2	0 (0.71)	0 (0.71)	0 (0.71)
3	0 (0.71)	0 (0.71)	0 (0.71)
4	0 (0.71)	0 (0.71)	0 (0.71)
5	0 (0.71)	0 (0.71)	0 (0.71)
6	0 (0.71)	0 (0.71)	0 (0.71)
7	0 (0.71)	0 (0.71)	0 (0.71)
8	0 (0.71)	0.66 (1.08)	1.0 (1.22)
9	0 (0.71)	0 (0.71)	2.0 (1.58)
10	0 (0.71)	0 (0.71)	0 (0.71)

Figures in the brackets are transformed data using Sq. Root x + 0.5 transformation.

Appendix 45. Mean number of *H. armigera* larvae/plant when maize was in pure stands when intercropped with cowpea (short rains 1987).

Replicates	Cropping system		
	maize/TVU 946	maize/ICV2	maize pure
I	0 (0.71)	0.4 (0.95)	0.8 (1.14)
II	0.4 (0.95)	0 (0.71)	0.4 (0.95)
III	0 (0.71)	0 (0.71)	0 (0.71)
Means	0.13 (0.79)	0.13 (0.79)	0.4 (0.93)

Figures in the brackets are transformed means using Sq. Root x + 0.5 transformation.

Appendix 45 cont.

Analysis of variance table

Source	Df	ss	ms	F
Treatments	2	0.06	0.03	2.72NS
Replicates	2	0.09	0.04	4.34NS
Error	4	0.03	0.01	
Total	8	0.81		

CV = 12.41 SE ± 0.11

.. NS- Denotes not significant at p = 0.05.

Appendix 46. Incidence of *E. saccharina* larvae or pupae/plant when maize was in pure stands and when intercropped with cowpeas (short rains 1987).

Weeks after emergence	cropping system		
	maize/TVU 946	maize/ICV2	maize pure
1	0 (0.71)	0 (0.71)	0 (0.71)
2	0 (0.71)	0 (0.71)	0 (0.71)
3	0 (0.71)	0 (0.71)	0 (0.71)
4	0 (0.71)	0 (0.71)	0 (0.71)
5	0 (0.71)	0 (0.71)	0 (0.71)
6	0 (0.71)	0 (0.71)	0.33 (0.91)
7	0 (0.71)	0 (0.71)	0.94 (0.97)
8	0.33 (0.91)	1.67 (1.47)	1.0 (1.22)
9	2.0 (1.58)	0.66 (1.08)	1.33 (1.35)
10	1.00 (1.22)	1.33 (1.35)	1.00 (1.22)
11	1.00 (1.22)	1.00 (1.22)	1.63 (1.28)
12	1.0 (1.22)	0.66 (1.08)	1.67 (1.47)

Figures in the brackets are transformed data using Sq. Root x + 0.5

Appendix 47. Mean numbers of *K. saccharina* larvae or pupae/plant when maize was in pure stands and when intercropped with cowpea (short rains 1987).

Replicates	cropping system		
	maize/TVU 946	maize/ICV2	Maize pure
I	0.60 (1.05)	0.60 (1.05)	2.67 (1.78)
II	1.40 (1.30)	1.40 (1.30)	0 (0.71)
III	1.20 (1.30)	1.0 (1.22)	1.0 (1.22)
Means	1.07 (1.24)	1.0 (1.22)	1.0 (1.22)

Figures in the brackets are transformed means using Sq. Root x + 0.5 transformation.

Appendix 47 cont.

Analysis of variance table

Source	Df	ss	ms	F
Replicates	2	0.03	0.014	0.09NS
Treatments	2	0.01	0.001	0.0001NS
Error	4	0.66	0.164	
Total	8	0.69		

CV = 32.41 SE ± 0.37

NS- Denotes not significant at p = 0.05.

Appendix 48 Incindence of *C. partellus* on maize when in pure stands and when intercropped with cowpea cultivars (long rains 1988).

Weeks after emergence	Cropping system		
	Maize/TVU 946	maize/ICV2	maize pure
1	0.04 (0.73)	0.08 (0.76)	0.04 (0.73)
2	1.29 (1.34)	0.25 (0.76)	1.29 (1.34)
3	1.92 (1.56)	0.83 (1.11)	2.50 (1.73)
4	1.79 (1.51)	2.67 (1.78)	2.96 (1.86)
5	1.46 (1.40)	0.92 (1.19)	1.58 (1.44)
6	2.00 (1.58)	0.75 (1.12)	2.13 (1.62)
7	1.21 (1.31)	0.83 (1.15)	1.13 (1.28)
8	0.38 (0.94)	0.47 (0.96)	0.29 (0.89)
9	0.42 (0.96)	0.38 (0.94)	0.58 (1.04)
10	0.58 (1.04)	0.46 (0.98)	0.54 (0.54)
11	1.96 (1.57)	0.67 (1.08)	1.71 (1.49)

Figures in the brackets are means transformed using $\sqrt{x + 0.5}$ transformation.

Appendix 49. Incidence of *C. partellus* larvae and pupae/plant when maize was in pure stands and when intercropped with cowpea cultivars (short rains 1988).

Weeks after emergence	Cropping system		
	Maize/TVU 946	Maize/ICV2	Maize pure
1	0.71	1.0	1.29
2	0.71	0.71	1.56
3	1.18	0.71	2.27
4	1.49	0.71	2.08
5	1.09	1.05	2.01
6	1.79	1.0	2.70
7	1.35	1.0	2.55
8	0.71	1.09	1.65
9	0.88	1.17	2.07
10	1.17	0.88	1.18
11	1.27	1.05	1.17

Data transformed using $\sqrt{x} + 0.5$ transformation.

Appendix 50. cont.

Analysis of variance table.

Source	DF	SS	MS	F
Treatments	2	2.12	1.06	3.16 NS
replicates	3	1.54	0.51	1.53 NS
Error	6	2.02	0.34	
Total	11	5.67		

CV = 16.67 SE $\pm$ 0.58 NS - not significant at p = 0.05.

Appendix 51. Mean number of *C. partellus* larvae and pupae/plant when maize was in pure stands and when intercropped with cowpea cultivars (short rains 1988).

Replicates	Cropping system		
	Maize/TVU 946	Maize/ICV2	Maize pure
I	2.89	1.99	4.49
II	2.79	2.22	3.45
III	1.74	2.01	4.11
Means	7.47	2.07	4.11

Data transformed using $\sqrt{x}$ + 0.5 transformation.

Appendix 51. cont.

Analysis of variance table.

Source	DF	SS	MS	F
Replicates	2	0.27	0.14	0.45 NS
Treatments	2	6.96	3.48	11.39*
Error	4	1.22	0.31	
Total	8	8.46		

CV = 19.16 SE ± 0.18.

* - Denotes significance at p = 0.05.
NS - Denotes not significant at p = 0.05.

Appendix 52. Mean cowpea grain weight in Kg/ha when cowpea cultivars were in pure stands and when intercropped with maize (short rains 1987)

Replicates	cropping system			
	TVU 946 pure	TVU 946 c/m	ICV2 pure	ICV2 c/m
I	2072.88	659.55	5789.28	1908.43
II	5202.60	563.55	5766.16	2639.08
III	3817.74	789.33	4640.80	1370.65
Means	3697.80	670. 81	5399.10	1972.40

Appendix 52 cont.

Analysis of variance table.

Source	Df	ss	ms	F
Cropping system(a)	1	3952.70	3952.70	42.62*
Varieties(b)	1	855.98	855.98	9.23*
Blocks	2	281.14	140.57	1.52NS
a vs b	1	15.12	15.12	0.16NS
Error	6	556.41	92.62	
Total	11	5661.35		

CV = 29.17 SE ± 9.63

* Denotes significant at p = 0.05.

Appendix 53. Maize grain yield in Kg/ha when it was in pure stands and when intercropped with cowpea cultivars (short rains 1987).

Replicates	Cropping system		
	Maize/TVU 946	Maize/ICV2	Maize pure
I	4815.51	4841.28	4505.00
II	4474.62	3400.85	5807.94
III	4678.18	4089.29	5738.16
Means	4655.10	4110.60	5350.17

Appendix 53 cont.

Analysis of variance table

Source	Df	ss	ms	F
Replicates	2	1173.22	586.61	2.25NS
Treatments	2	57.56	28.78	0.11NS
Error	4	1041.46	260.36	
Total	8	2272.23		

CV = 15.23 SE ± 16.14

NS Denotes not significant at p = 0.05

Appendix 54. Mean grain weight of cowpea in Kgs/Ha when cowpea cultivars were in pure stands and when intercropped with maize(long rains 1988).

Replicates	Cropping system			
	TVU 946 pure	TVU 946 C/M	ICV2 C/M	ICV2 pure
I	2745.89	469.92	572.59	962.06
II	1586.43	570.92	2282.13	1201.03
III	2636.36	1178.95	1376.47	1609.28
IV	1223.32	403.22	1069.51	1346.80
Means	2047.99	655.75	1325.18	1279.79

Appendix 54 cont.

Analysis of variance table.

Source	DF.	SS	MS	F
Cropping system (a)	1	1234243.23	1234243.23	3.52***
Variety (b)	1	38427.76	38427.46	0.11 NS
Blocks	3	632513.07	210837.69	0.60 NS
a vs b	1	179660.14	179660.14	5.12*
Error	9	3155733.80	350637.09	
Total	15	6857523.01		

CV = 42.72. SE ± 24.33.

NS - not significant at p = 0.05.

* - significant at p = 0.05.
** significant at p = 0.20.

Appendix 55. Mean maize grain yields in Kgs/Ha when in pure stands and when intercropped with owpea cultivars (long rains 1988).

Replicates	Cropping system		
	Maize/TVU 946	Maize/ICV2	Maize pure
I	1156.87	968.88	1129.32
II	2081.76	1298.65	1659.54
III	2346.19	1650.65	1910.20
IV	1505.76	2690.19	2196.42
Means	1772.65	1652.09	1773.87