Fall Armyworm and Neotropical Cornstalk Borer on Sorghum and Maize Intercropped with Legumes in Honduras[1]

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ABSTRACT

The effects of intercropped legumes on densities of fall armyworm -FAW- (*Spodoptera frugiperda* (J.E. Smith)) and neotropical corn stalk borer -NCSB- (*Diatraea lineolata* (Walker)) on sorghum (*Sorghum bicolor* (L.) Moench) and maize (*Zea mays* (L.)) were studied in central Honduras in 1986 and 1987. Sorghum and maize intercropped in the same hill were compared with intercropped sorghum-maize-pigeonpea in 1986 at Rapaco, El Paraíso, and with sorghum-maize-cowpea in 1987 at Rapaco and El Zamorano, Francisco Morazán in 1987. Infestations of FAW on sorghum and maize were similar for plots with or without pigeonpea in 1986. In 1987 sorghum and maize with cowpea had lower infestations of FAW than the intercropped system without cowpea at both locations. Infestations of NCSB were not affected by intercropping pigeonpea or cowpea with sorghum and maize. Numbers of adults and eggs of the predaceous earwig (*Doru taeniata* (Dohrn)) were similar in plots with or without pigeonpea in 1986, but they were higher in plots with cowpea in 1987. Parasitoids were not influenced by cropping system.

Key words: Sorghum, maize, legumes, intercropping, insects.

RESUMEN

Se estudiaron los efectos de leguminosas intercaladas en el grado de infestación del gusano cogollero del maíz (*Spodoptera frugiperda* (J.E Smith)) y del lepidóptero (*Diatrea lineolata* (Walker)), en sorgo (*Sorghum bicolor* (L.)) y maíz (*Zea mays* (L.)) en Honduras, en 1986 y 1987. Se compararon los cultivos intercalados de sorgo y maíz en el mismo lugar con el de sorgo-maíz-gandul, en 1986 en Rapaco, El Paraíso, y de sorgo-maíz-caupí en 1987 en Rapaco y El Zamorano, en Francisco Morazán. Las infestaciones de gusano cogollero en sorgo y maíz fueron similares en los lotes con o sin gandul en 1986. En 1987, el cultivo intercalado de sorgo-maíz con caupí presentó infestaciones más bajas de gusano cogollero que en aquel sin caupí en ambos sitios. Las infestaciones de gomosis de maíz no fueron afectadas por la asociación gandul o caupí con sorgo y maíz. El número de adultos y de huevos de tijeretas (*Doru taeniata* (Dohrn)) fueron similares en los lotes con o sin gandul en 1986, pero fueron más altos en los lotes con caupí en 1987. Los parasitoides no fueron influidos por el sistema de cultivos intercalados.

INTRODUCTION

Cropping systems in the tropics commonly include the practice of growing two or more crops in the same space with some overlap of their growing period (intercropping) (Willey 1979). Crop associations may consist of cereal-cereal or cereal-legume systems (Diaz 1982, Willey 1979). In southern Honduras, more than 90% of the sorghum, *Sorghum bicolor* (L.) Moench, is intercropped with maize, *Zea mays* (L.) (Anonymous 1974). Field bean, *Phaseolus vulgaris* L., is a preferred plant protein in southern Honduras and it may be intercropped with maize or sorghum. However, it does not grow well in this area because of inadequate rainfall. Maximum yields of legumes in southern Honduras have been reported at 674 kg/ha for field bean, 1089 kg/ha for pigeonpea, *Cajanus cajan* L., and 2115 kg/ha for cowpea, *Vigna unguiculata* (L.) Walpers (Anonymous 1986). Cowpea and pigeonpea appear to be the most promising legumes

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for intercropping with sorghum and maize in the hot, dry region of southern Honduras. Because of their drought tolerance and high yield potential, they are alternatives to *P. vulgaris* in this region.

Intercropped cereals and legumes have been recognized to have yield advantages over monocultures. Such combinations include maize-beans (Francis *et al.* 1982a,b; Paul *et al.* 1987a,b), sorghum- beans (Paul *et al.* 1987a,b), sorghum-cowpea (Faris *et al.* 1983; Davis *et al.* 1985; Willey 1982), and sorghum-pigeonpea (Willey 1982). The traditional intercropping practices of the subsistence farmer are considered desirable in terms of their efficient resource use, improved farmer nutrition (cereal plus legume), and reduced pest infestation and insects damage.

The insect pests in intercropped sorghum-maize-legume systems in Honduras have not been investigated. Data for cereal-cereal and cereal-legume cropping combinations show that some reduction in insect numbers may be encountered in these intercropped systems in comparison with monocultures. In Africa, sorghum intercropped with millet had lower infestations of stem borer larvae than sorghum in monoculture (Adesiyun 1983). In southern Honduras, sorghum intercropped with maize had lower larval infestations of fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), than sorghum in monoculture (Castro *et al.* 1989). Efficiency of cropping systems, in terms of resource use, is expected to be greater when crops differ in growth periods or habits because of partitioning of the time or type of resource demand.

Differences in plant morphology or physiology under intercropping also may result in lower numbers of insect pests. Some species of insect pests were observed in lower numbers when certain cereals were intercropped with legumes. In Colombia, intercropped maize and beans were infested with lower numbers of FAW than monocropped maize (Altieri 1980). The earlier that beans were planted relative to maize, the greater was the reduction in infestation of maize. Similar observations were made in Nicaragua (Van Huis 1981). Intercropping cowpea with maize and sorghum reduced the incidence of stem borers on cereals in Kenya (Omolo and Seshu Reddy 1985). Infestations of chrysomelid beetles were reduced on squash and beans when intercropped with maize, a non– host plant, in Costa Rica (Risch 1981).

Two of the most important insect pests of sorghum and maize in southern Honduras are the FAW (Koone and Banegas 1958; Andrews 1988) and the neotropical cornstalk borer (NCSB) (Koone and Banegas 1958). The impact of these pests and the role of natural enemies in relation to pest populations has not been defined in most agricultural systems in this area. The interactions of crop and non-crop vegetation with insects in intercropping systems creates interesting biological relationships, some of which can be beneficial to crop production (Willey 1979). This study was conducted to de-termine infestations of FAW and NCSB and related na-tural enemies in cropping systems in which legumes were intercropped with sorghum and maize in Honduras.

MATERIALS AND METHODS

Study 1

Sorghum-maize and sorghum-maize-pigeonpea intercrops (treatments) were planted on 16 June 1986 in 27 x 27 m plots at Rapaco in the Department of El Paraíso, Honduras. Treatments were arranged in a randomized complete block design (four replications). Sorghum seed (6 - 9) and maize seed (4 - 6) were planted in the same hill (*casado*) in both treatments, each hill separated by 1 m, and pigeonpea seeds (3 - 5) were planted at 0.5 m between every other sorghum-maize hill in each row (to reduce competition between the cereals and pigeonpea). Rows were 27 m long and were separated by 0.8 m. The improved *maicillo criollo* sorghum (TAM428 x Porvenir)-bk (with high yield potential), *Planta Baja* maize (early maturity type), and ICPL-290 pigeonpea (adapted to Honduras) varieties were used. Plots were fertilized with 60 kg/ha of 18 -46 - 0 and kept weed free (manually) throughout the growing season. No herbicides or other agrochemicals were used in the study plots.

Twenty plants each of sorghum and maize were randomly sampled for insects in each treatment plot weekly from 14 July (seedling stage) to 21 November (milk stage of sorghum). Whole plants were examined visually using a destructive sampling technique (Castro *et al.* 1989). The number of leaves per plant was recorded to relate plant phenology to insect numbers. Number of FAW larvae, larval size class (= instar), and number of eggs and adults of the predaceous earwig *Doru taeniata* (Dohrn) per plant were recorded. Stalk samples were taken from 22 August (mid-whorl) to 11 November (flowering). Stalks were dissected to determine the presence of NCSB larvae. Sample size and frequency of sampling for stalk borers were the same as for the FAW. Larvae were placed in 1 oz plastic cups containing an artificial diet (Bio-Mix 9781, Bio- Serv, Inc.) and held at room temperature to observe diapause condition and record emergence of parasitoids. Pigeonpea was not sampled because the insects emphasized in this study do not infest this crop. Crop yields were measured at normal harvest.

Comparisons among means were made for cropping systems and crop species. Data were analyzed with orthogonal comparisons or with F tests (Steel and Torrie 1980). Analyses were performed separately for data collected on each sample date.

Study 2

Sorghum-maize and sorghum-maize-cowpea plots were planted 14 June 1987, using the same plot size, management, and planting arrangement for sorghum and maize describe for the preceding study at the same location. Fertilizer was not used in 1987 in order to have conditions similar to those found on subsistence farms. Cowpea seeds (3 - 5) were planted in two hills 0.33 m apart between the sorghum-maize hills (each hill of cowpea was 0.33 m from the cereal seed in the same row). The same sorghum and maize varieties were used as in 1986 and the cowpea variety was BG401172. Cowpea was inoculated with cowpea specific *Rhizobium* (Nitragin) at twice the recommended dose. Cowpea was used in 1987 because of its higher yield potential and better protein quality than pigeonpea. Procedures for sampling plants, examination for insects, and analysis of the data were as described for Study 1.

Study 3

Sorghum-maize or sorghum-maize-cowpea treatment plots were planted in a tilled field between 5 July 1987 (sorghum and maize) and 18 July (cowpea) to observe the effect of cowpea plant age on insect infestations. Plots were 9 m x 10 m in a randomized complete block design with four replications. The test was located at El Zamorano, Department of Francisco Morazán. An untilled, adjacent field was planted with these same crops using the same experimental design as that in the tilled field. Untilled fields are representative of the hill-side farming practiced by many subsistence farmers in Honduras. The varieties used were EIME 133 sorghum (improved *maicillo* with high yield potential), *maicito* maize (early maturing native cultivar) from Pespire, Honduras and IT81D-1020 cowpea (similar grain size and color as the field bean, a preferred food crop of subsistence farmers). Cowpea was inoculated with a cowpea specific *Rhizobium*. Sorghum-maize hills were separated by 1 m; two hills of cowpea were planted between the sorghum-maize hills as described in Study 2. Rows were 10 m long and 1 m wide.

Insects were sampled by selecting 12 plants at random in each of the eight treatment plots in the tilled and untilled areas. The destructive plant examination technique was used. Data were taken on the number of FAW larvae and *D. taeniata* adults and analyzed as in Study 1. Comparisons between tilled and untilled plots were made with paired T-tests.

RESULTS AND DISCUSSION

FAW was the most common foliage feeder, NCSB was the principal stalk borer, and the earwig *D. taeniata* was the most common insect predator observed in the study fields. *D. taeniata* preys on both FAW (Sequeira 1986) and NCSB (Jones *et al.* 1989). These species were emphasized for intercrop systems and host comparisons in this study.

Study 1

Numbers of FAW were similar on sorghum plus maize (combined analysis) whether intercropped with pigeonpea or not throughout most of the 1986 test period except for 14 July when plots with pigeonpea had greater infestations (Fig. 1). Larvae of FAW were not detected on sorghum after 22 August, even though sorghum was in the whorl stage through late October. At the time of maximum FAW infestation (14 - 21 July), most of the larvae on sorghum (Fig. 2a) and maize (Fig. 2b) were small (1st and 2nd instars) to medium (3rd and 4th instars). By 15 August, the larvae on maize were large (5th and 6th instars), while on sorghum, only 15% of the larvae were large. Ashley *et al.* (1985) reported that the number of first instar FAW larvae is significantly negatively correlated with maize plant height. As the maize plant matures, it becomes less attractive to

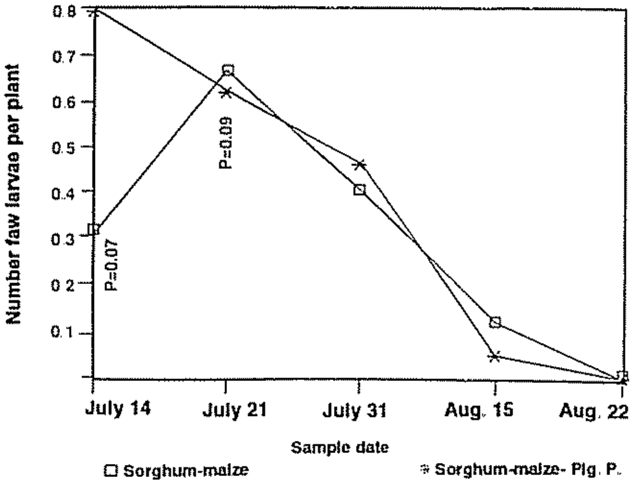

Fig.1. Number of fall armyworm (FAW) larvae per sorghum and maize plant (plant species pooled) in sorghum - maize-pigeonpea (-Pig.P) intercrop plantings (Rapaco, Hond., 1986).

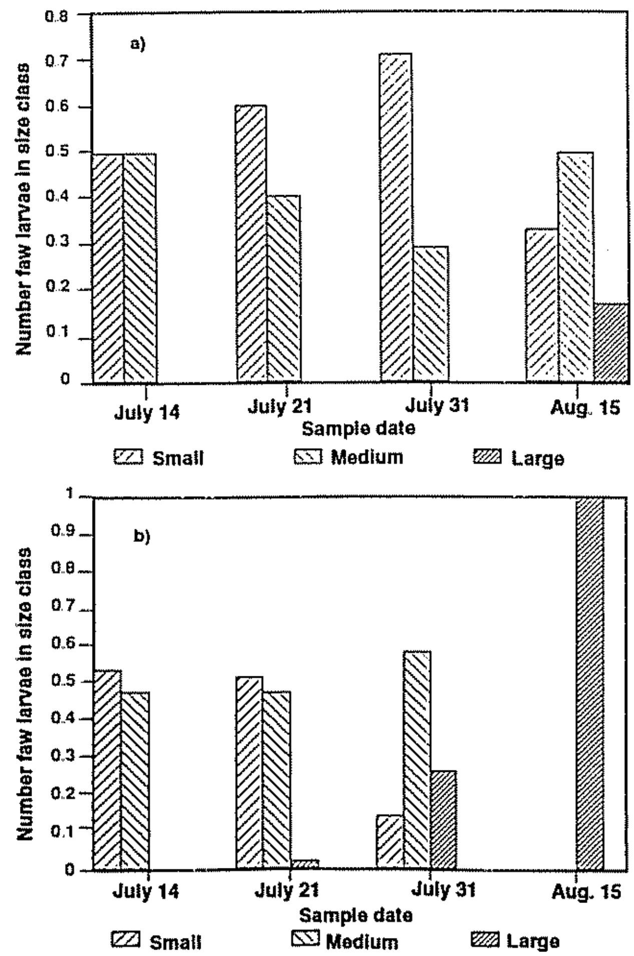

Fig. 2. Size of fall armyworm (FAW) larvae on a) sorghum and b) maize. Larvae size class: Small (1st and 2nd instars), medium (3rd and 4th instars), large (5th and 6th instars), (Rapaco, Hond. 1986).

FAW for oviposition; thus, fewer, early instar larvae can be expected to be found on the older plants. This agrees with the observations of this study that fewer early instar were found on the plants as they matured.

In studies in southern Honduras (Castro *et al.* 1989), FAW was observed to have two generations on sorghum. Results from this study indicate that FAW developed through only one complete generation on sorghum in central Honduras. Perhaps lower temperatures in central compared to southern Honduras were responsible for this slower development of the insect.

Numbers of FAW per plant in the two systems, with and without pigeonpea, were lower on sorghum than on maize from 14 July to 31 July. Infestations of FAW on maize exceeded 1 larva per plant (L/P); whereas, on sorghum, peak infestation was close to 0.25 L/P. Ovipositing females mainly are responsible for host-plant selection, but larvae also may detect plant odors and move from one plant to another (Visser 1986). This activity was recorded for the noctuid *S. littoralis* (Boisd.) which responded to compounds present in cotton leaves (Khalifa *et al.* 1973). In olfactometer tests FAW larvae have been shown to orient more frequently to bermuda grass than to zoysia grass (Chang *et al.* 1985). Other observations indicate that lepidopterous larvae may be attracted to host plants from distances up to only 4 cm, but the adult is more sensitive to odors (Visser 1986). Studies show that FAW females lay more eggs on maize than sorghum even when grown together (Van Huis 1981). It is a apparent that increased oviposition on maize over sorghum is, in part, responsible for the observed higher incidence of FAW larvae on maize than on sorghum.

The presence of pigeonpea did not affect sorghum stalk infestation by NCSB (Fig. 3a), and few differences between the two cropping systems were seen in the occurrence of this pest on foliage (Fig. 3b). The highest number of NCSB larvae on the foliage of sorghum plants was recorded on 9 - 16 October. While infestation by NCSB on sorghum foliage decreased (Fig. 3b), the number of borer larvae in sorghum stalks increased (Fig. 3a). Larvae of NCSB infested maize stalks more heavily than sorghum throughout the season, even after maize maturity (late August) (Fig. 4).

Farmers intercropping sorghum and maize in Honduras generally do not remove maize stalks after maturity. Although it is not known if stalk removal reduces

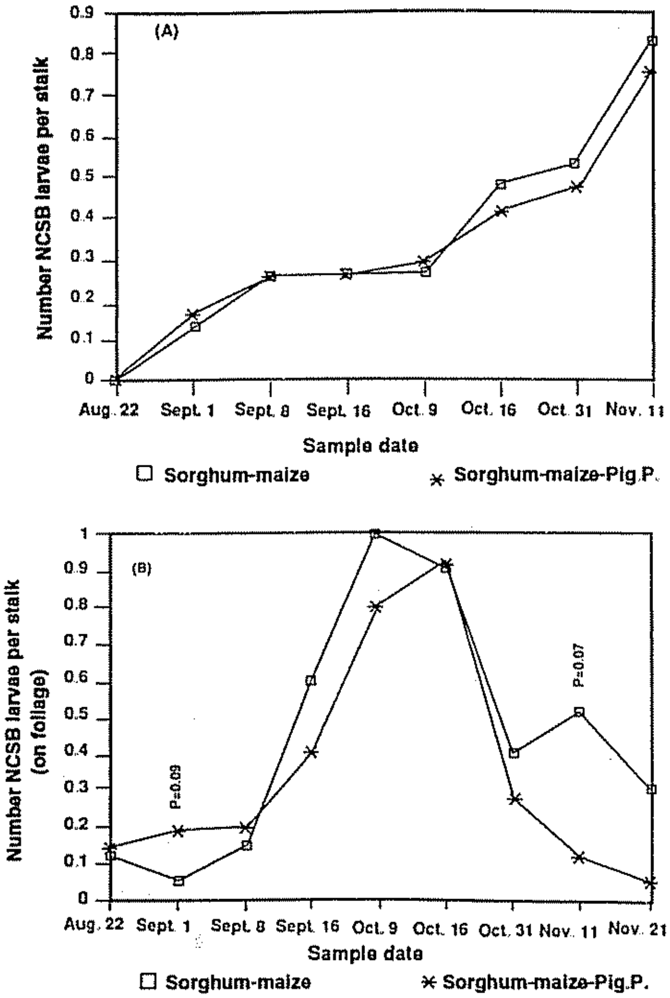

Fig. 3. Number of neotropical cornstalk borer (NCSB) larvae per sorghum a) stalk and b) foliage in sorghum maize or sorghum-maize– pigeonpea (-Pig.P) intercrop planting (Rapaco, Hond. 1986).

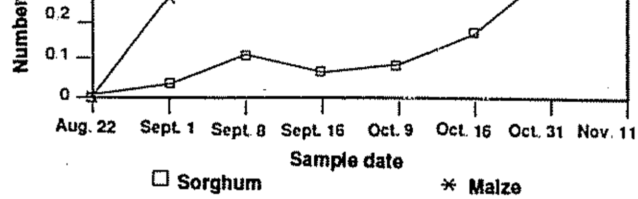

Fig. 4. Number of neotropical cornstalk borer (NCSB) larvae per sorghum or maize stalk in combined sorghum-maize and sorghum-maize–pigeonpea (-Pig.P.) intercrop planting (Rapaco, Hond. 1986).

or increases infestation of borers in sorghum, larvae of NCSB are known to survive in aestival diapause (Kevan 1944) during January through May (Andrews 1984) in the stalks. In 1986 at Rapaco, about 65% of the diapausing (aestivating) larvae were found in the middle third of the plant (stalk position) in both cropping systems. This suggests that the traditional practice of stovering the crops during the dry period can result in high mortality of the stalk borers in the diapause stage; consequently, the subsequent population of borers may be smaller.

Infestation of maize ears by NCSB reached 0.7 larvae per ear in both intercropping systems. Numbers of FAW were lower than NCSB in maize ears, but no significant effects of pigeonpea intercropping on the total number of either pest in the ears were observed.

No differences were observed between numbers of adult *D. taeniata* per plant in the cropping systems with and without pigeonpea, indicating that intercropping pigeonpea with sorghum and maize did not influence numbers of this predator in the system. However, numbers of *D. taeniata* adults per plant (D/P) were generally significantly greater on maize than on sorghum. Two peaks in numbers (numbers for two systems) of *D. taeniata* were observed in the cropping systems, the first (4.9 D/P) following maize pollination and the second (2.9 D/P) following sorghum pollination. This may be attributed to pollen abundance, which provides an alternate food source for the earwigs. Similar observations were made by Sequeira (1986). The density of *D. taeniata* egg masses in the system without pigeonpea was equal to that with pigeonpea. The number of *D. taeniata* egg clutches per plant was higher on maize (1.7 clutches) than on sorghum (0.5 clutches) at maize pollination and highest on sorghum at sorghum pollination.

Number of *D. taeniata* increased in mid-to late August, during which time FAW numbers were declining to near zero levels and maize pollination was taking place. The increase in number of *D. taeniata* adults appeared to be independent of the infestation of FAW larvae but was more closely related to availability of the pollen source.

Chelonus insularis Cresson (Braconidae) was the most common parasitoid of FAW larvae and parasitized 60% - 66% of the larvae during mid-late July in Rapaco. Other parasitoids encountered (percent parasitization) included *Eiphosoma viticolle* Cresson (Ichneumonidae)

Table 1. Yields in sorghum-maize, sorghum-maize-pigeonpea and sorghum-maize-cowpea systems (Rapaco, Hond., 1986 and 1987).

	System[a]	Yield (t/ha)			
		Sorghum	Maize	Pigeonpea	Cowpea
1986					
	S-M	1.3a[b]	2.3a	-	-
	S-M-P	1.1b	2.4a	0.3	-
1987					
	S-M	-[c]	0 6a	-	-
	S-M-C	-[c]	0.4a	-	0.3

a. System: S-M= Sorghum-maize; S-M-P= Sorghum-maize-pigeonpea; S- M-C= Sorghum-maize-cowpea.
b. Means followed by the same latter are not significantly different at P= 0.05 level with Duncan's multiple range test.
c. Sorghum not harvested.

(2% - 5%), *Rogas vaughani* Muesebeck (Braconidae) (4%), and *Archytas marmoratus* (Townsend) (Tachinidae) (4%). The nematode *Hexamermis* sp., which is a common parasitoid of FAW larvae in some areas of southern Honduras (Castro *et al.* 1989), was not present in the study plots at Rapaco.

Crop yield

Maize yield in the sorghum-maize-pigeonpea system was not affected by intercropping with pigeonpea (Table 1), but sorghum yield was reduced significantly. This reduction in yield of sorghum may be offset by yield of pigeonpea in this cropping system. Additionally, pigeonpea is an important protein source in the farmers' diet or that of their livestock.

Growth of sorghum and maize plants in the pigeonpea intercropped system was not significantly affected. The number of leaves per plant and plant growth profiles were the same for sorghum and maize in both cropping systems. These findings support the observations that legume intercropping is considered desirable for sorghum-based production systems in southern Honduras (DeWalt and DeWalt 1982).

Study 2

FAW infestation was significantly higher in the sorghum-maize system than in the sorghum-maize-cowpea system on 2 of 6 sample dates at Rapaco in 1987 (Fig. 5). On these two dates (July 24 and July 30), most of the larvae were of small to medium size (1st - 4th instars) on sorghum (Fig. 6a) and on maize (Fig. 6b). Crop damage would not be expected to be great in these situations because 1st through 4th instars consume less than 10% of the amount of food required for larval development (Sparks 1979). When most of the larvae were large (5th and 6th instars) in sorghum and maize (13-20 August), no differences in numbers of larvae were observed between the two cropping systems (Fig. 5). Numbers of FAW larvae were higher on maize (0.4 larvae per plant) than on sorghum (0.2 larvae per plant) and declined to near zero by late August. Although sorghum remained in the whorl stage until late October, larvae were not detected on sorghum plants after 28 August. However, small numbers of FAW larvae were present in maize ears at this time.

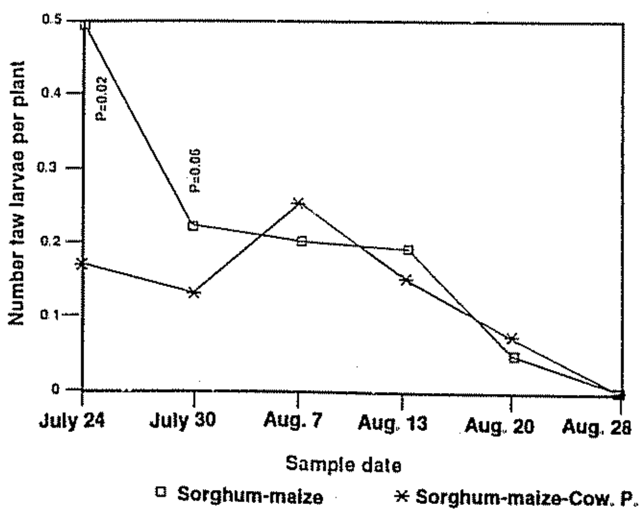

Fig. 5. **Number of fall armyworm (FAW) larvae per sorghum and maize plant (plant species pooled) in sorghum-maize or sorghum-maize– cowpea (-Cow.P.) intercrop planting (Rapaco, Hond. 1987).**

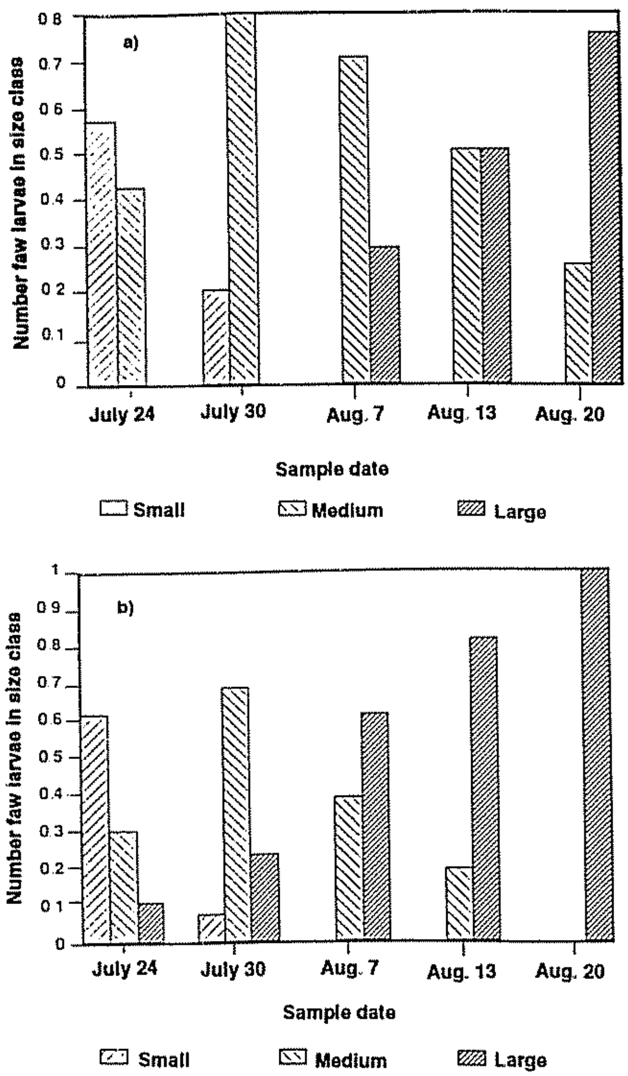

Fig.6. Size of fall armyworm (FAW) larvae on a) sorghum and b) maize. Larvae size class: Small (1st and 2nd instars), medium (3rd and 4th instars), and large (5th and 6th instars), (Rapaco, Hond. 1987).

The presence of cowpea in the crop system may have interfered with the host finding process FAW moths. Odors emitted by plants consist of complex blends of chemicals. Olfactory orientation of some insects to selected chemicals may be distorted by mixing the odors of host and non-host plants (Visser 1986) or by a change in the ratio of odor components in the host plant (Visser and Ave 1978). A review of host odor perception in phytophagous insects (Visser 1986) supports the "resource concentration" hypothesis (Root 1973). This hypothesis may explain the lower number of FAW on sorghum and maize when cowpea is present; the cowpea plants may interfere with the moth's host-finding ability.

Infestation of sorghum stalks by NCSB was lower in 1987 (0.3 larvae per stalk) than in 1986 (about 0.8 larvae per stalk), and no differences were observed between cropping systems with or without cowpea (Fig. 7). The differential in plant height between sorghum and cowpea or sorghum and pigeonpea (Study 1) when NCSB moths were laying eggs on the sorghum may have nullified the interference effects with the moth's host finding ability. The more comparable plant growth profiles of the sorghum and pea plants when FAW moths were laying eggs on the sorghum appeared to influence the moth's host-finding ability.

Larvae of NCSB were more common in the whorl than on older leaves during mid-to late September, after which larvae were more common on older leaves. This movement from the whorl to the older leaves corresponds to the increased infestation in sorghum stalks in October (Fig. 7). Damage to sorghum by NCSB was concentrated in the middle third of the plant and was not different for the two systems. The proportion of diapausing NCSB larvae in sorghum in November and December was also higher (66%) for the middle third of the plant, as was observed in 1986. In southern Honduras, 87% of the farmers stover the sorghum and maize crop residue (Díaz 1982). As suggested in Study 1, the practice of feeding cattle with crop residues would contribute to the mortality of diapausing NCSB.

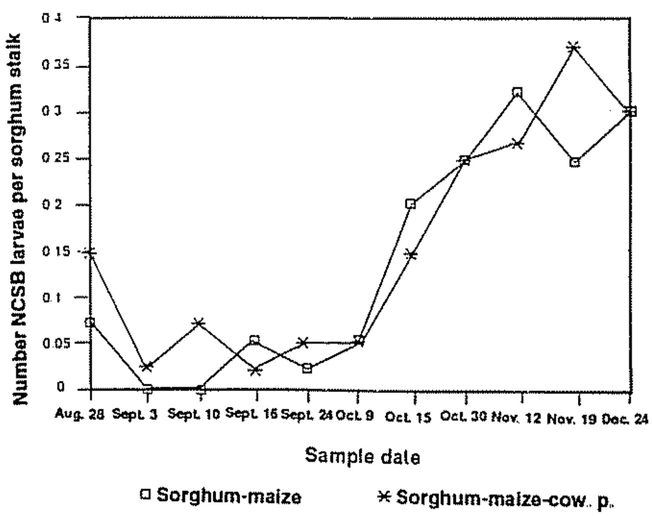

Fig. 7. Number of neotropical cornstalk borer (NCSB) larvae in sorghum stalks in sorghum-maize or sorghum-maize-cowpea (-Cow.P.) intercrop plantings (Rapaco, Hond. 1987).

No difference was observed for degree of parasitism of FAW between sorghum-maize and sorghum-maize-cowpea intercropping systems. Parasitism of FAW larvae in 1987, as in 1986, was highest by *C. insularis* (85% - 37%), but parasitism by *E. viticolle* was higher (11% - 27%) than in 1986. Various weekly observations of other FAW parasitoids included *R. vaughani* (9%), *A. marmoratus* (44%) and *Lespesia* sp. (Tachinidae) (5% - 30%). The fungus *Nomurea rileyi* (Farlow) caused high FAW mortality (33% - 40%) in mid-to late August. The mermithid nematode *Hexamermis* sp. was absent (as in 1986), strongly suggesting that it contributes little, if any, to FAW mortality in central Honduras in contrast to southern Honduras (Castro *et al.* 1989).

Sorghum and maize intercropped with cowpea had higher number of *D. taeniata* per plant than the sorghum-maize intercropped system. The reduced incidence of FAW larvae in sorghum-maize cowpea on 24 and 30 July cannot be explained by an increase in the number of *D. taeniata*, which was similar for both systems on these dates. The increase in *D. taeniata* that occurred between 7 - 20 August, was not associated with FAW because small (1st and 2nd instars) larvae were not found on sorghum (Fig. 6a) or maize (Fig. 6b) at that time. However, maize pollination was taking place and the pollen apparently provided a significant food source. Unlike 1986, the number of *D. taeniata* per plant was not consistently higher on maize than on sorghum. This possibly may be due to lower rainfall in August 1987. Maize was affected more severely by the drought than sorghum which was in the vegetative stage. The highest number of *D. taeniata* per plant was 1.4 and 1.7 on sorghum and maize, respectively, in 1987, which was much lower (1/3 less) than levels reached in 1986. The dries conditions in 1987 may have contributed to this difference between years. Interestingly, *D. taeniata* eggs were more common on maize than on sorghum, and on ears than on leaves, at the time of maize maturity.

Early in the season no difference was found between the number of *D. taeniata* in sorghum whorls and on leaves, but as the season progressed most of the earwigs were found in the whorl. This difference was significant from 24 September to 30 October. The whorl provided a more humid environment than the leaf sheaths, protecting the earwigs from desiccation. After sorghum flowering, the earwigs were significantly more common on the panicles than on the leaves, and remained so from 12 November 1987 to 7 January, 1988.

The "natural enemies" hypothesis (Pimentel 1961) accounts for a reduction in pest numbers in diverse compared to simple agroecosystems as being due to increased numbers of parasites and predators. However, mortality due to natural enemies does not appear to differ between simple and diverse systems (Tahvanainen and Root 1972; Root 1973). Thus, the "resource concentration" hypothesis was proposed by Root (1973) to explain higher densities of phytophagous insects in simple versus diverse systems (Tahvanainen and Root 1972; Root 1973). As stated previously, it implies that the herbivores' host finding ability is adversely affected by the presence of non-host plants. Results of studies with 198 herbivore species showed that in comparisons between simple and diverse systems, 53% of the species were less abundant in the more diverse system, 18% were more abundant, 9% showed no differences and 20% had variable responses (Risch *et al.* 1983).

Crop yield

Maize yield was much lower in 1987 than in 1986, and yields were similar for plots with or without cowpea (Table 1). Sorghum yield was not measured in 1987 due to our inability to be in the fields at the time of harvest. The additional of cowpea in the sorghum-maize-cowpea intercrop system would be expected to compensate for anticipate reduction in sorghum yield (as observed in Study 1). Intercropping cowpea with sorghum and maize did not significantly affect plant growth of the cereals.

Study 3

Insect densities in intercropping systems may be influenced by farming practices such as tillage or no-tillage. No-till cropping practices increase the amount of mulch on the soil surface. This improve soil physical properties and soil fertility, which in turn may increase crop yields; however, lack of tillage also may increase pest incidence (Lal 1987). This third study was conducted at El Zamorano to compare insect infestations on sorghum-maize and sorghum-maize-cowpea intercropping systems in tillage and no-tillage systems.

The number of FAW larvae on maize was lower (P=0.03) for the plots with intercropped cowpea (0.9 larvae per plant) than plots without cowpea (1.2 larvae per plant) on the date (12 August) of highest infestation of maize. Lower (P=0.03) numbers of FAW larvae were collected on sorghum plants in plots with cowpea (0.1 larvae per plant) than on sorghum in plots without cowpea (0.5 larvae per plant) at peak FAW infestations on sorghum on 8 September. Tillage had no effect on FAW infestations on maize or sorghum.

At El Zamorano in central Honduras, FAW larvae were parasitized by *C. insularis* (2% - 49%), *Rogas laphygmae* Viereck (2%), *A. marmoratus* (3% - 4%), and *Lespesia* sp. (3% - 16%). The mermithid nematode *Hexamermis* sp. was recovered at El Zamorano, but in lower numbers (4% - 14%) than usually found in southern Honduras (Castro *et al.* 1989). The pathogen *N. rileyi* was more prevalent at El Zamorano than at Rapaco.

The earwig *D. taeniata* was more common (P=0.1) in the plots with no-till (0.2 adults per plant) than in tilled plots (0.1 adults per plant) at the time of peak FAW infestation. No-till plots had higher density of the grass *Paspalum* sp. than tilled plots. This grass appeared to provide shelter or possibly alternate food sources for the earwigs.

CONCLUSIONS

Intercropping pigeonpea with sorghum and maize did not influence densities of FAW or NCSB larvae, or adults of the earwig *D. taeniata* on the cereals. When cowpea was introduced into the sorghum-maize intercropped system, numbers of FAW larvae on the cereals were significantly lower on two of six sample dates early in the crop growing season, whereas *D. taeniata* was more abundant late in the season on the cereals. The lower numbers of FAW early in the growing season can not be attributed to he earwig predator. It is possible that cowpea plants interfered with the host-finding process of FAW adults, thus reducing the numbers of eggs and larvae on the crops. Numbers of NCSB larvae were not affected by the presence of cowpea in the system. Parasitism of FAW larvae was not affected by legume intercropping. Generally, intercropping legumes with sorghum and maize did not increase numbers of FAW or NCSB larvae on the cereals.

Maize yield was not affected by intercropping pigeonpea or cowpea with the cereals, although sorghum yield was reduced when intercropped with pigeonpea in these studies. The additional yield from the legume crop compensates for lower yield of sorghum. The legume in these systems should be of significant value in the diet of subsistence farmers.

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