Populations of fall armyworm, *Spodoptera frugiperda* (J. E. Smith), larvae and associated natural enemies in sorghum and maize cropping systems in southern Honduras

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Fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), larvae populations were investigated in three studies, including sorghum [*Sorghum bicolor* (L.) Moench] in pure stand, and sorghum and maize (*Zea mays* L.) in intercropping and mixed cropping systems, established at Choluteca in southern Honduras. Early instar larvae infested the young sorghum hybrid Catracho (AT · 623 · Tortillero) in pure stand approximately ten days after emergence and persisted throughout the whorl stage (2 June–4 August) during the first growing season (primera) of the crop in 1983. In a small plot study in that year Catracho sorghum and the early maturing native maize variety, Tusa Morada, were planted in alternate hill ('golpe alterno'), alternate row ('surco alterno'), pure stand, and same hill ('casado') systems. Fewer sorghum plants than maize plants were infested with FAW larvae, except in the 'golpe alterno' system. In a third study, using the tropical indigenous sorghum variety Liberal and Tusa Morada maize in 1984, sorghum with a natural weed infestation and the 'casado system' had lower FAW infestations than sorghum with a maize trap crop and pure stand sorghum. A nematode (Mermithidae) was the most common parasite of the FAW in both years. Parasitization (up to 71%) of larvae by this endoparasitic nematode increased as rainfall increased; precipitation accounted for 93% of the variation in parasitization.

Keywords: Fall armyworm, *Spodoptera frugiperda*; Larvae; Natural enemies; Sorghum; Maize; Southern Honduras

Sorghum is generally intercropped with maize on small farms in Honduras because it tolerates an adverse environment characterized by erratic rainfall, high temperatures and low soil fertility. When the maize crop fails from drought, resource scarce farmers often substitute sorghum grain for maize in making tortillas to feed themselves and their families (DeWalt and DeWalt, 1984); and the grain and crop residues are fed to livestock.

Native landrace sorghums called 'maicillo criollos' grown by subsistence farmers in fields averaging 1.5 ha in Honduras are tall (3–4 m) and sensitive to photoperiod. 93% of the sorghum grown in Honduras is intercropped with maize (SRN, 1980). Because of its sensitivity to photoperiod, sorghum does not differentiate and begin internode elongation until the first part of October (Meckenstock *et al.*, 1985) after maize reaches maturity and is harvested. The intercropping of late maturing, photoperiod sensitive sorghums with early maturing maize varieties effectively utilizes the limited land available and soil moisture and nutrients by staggering the reproductive phase of the two crops to reduce competition between them during their respective growth and development (Donaire, 1982).

The fall armyworm (FAW), *Spodoptera frugiperda* (J. E. Smith), is a principal constraint to sorghum and maize production in southern Honduras (DeWalt and DeWalt, *ibid*). It can cause yield loss by defoliation or as a cutworm by killing plants during the seedling growth stage. The larvae also feed on the grain, but on-farm observations in Honduras suggest that other lepidopterous species are more important as grain feeders. Yield losses of 51% in sorghum have been reported using artificial larval infestations of one large larva plant^{-1} (Andrews, 1980).

Alieri (1980) reported that in most agricultural systems lower herbivore populations are observed when one crop species is interplanted with other crop species or intermingled with weed communities. In Colombia he found heavier FAW larval infestations in pure stands of maize than in maize and bean intercropped plots and in maize plots with weeds. While working in Florida, he also found that

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FAW densities in maize monoculture were twice as high as those in maize with-weeds.

Since sorghum-maize intercropping is prevalent in Honduras and because maize is more attractive than sorghum to FAW moths for oviposition (Sifuentes, 1967; Van Huis, 1981), the influence of component crops in spatial arrangements and in pure stand on FAW infestations was investigated. Fall armyworm infestations were measured in sorghum and maize in pure stands, sorghum-maize intercrops, pure stand sorghum with a maize trap crop to isolate larval infestations for spatially limited application of control measures, and in a weed-infested sorghum planting system to determine the influence of weeds on FAW infestations. Additionally, parasitization of FAW larvae was determined in the different sorghum and maize cropping systems in southern Honduras. Possible explanations for the observed results and proposals for future studies are presented.

Materials and methods

1983 – Study 1

A 3 ha pure stand of the sorghum hybrid Catracho (AT×623 × Tortillero) was planted 20 May 1983 in rows 200 m long and 0.8 m wide at the La Lujosa Experiment Station of the Ministry of Natural Resources in Choluteca, Honduras, to observe FAW population infestations on the hybrid sorghum during plant growth and development. Catracho is a two-dwarf commercial hybrid, released by the Ministry of Natural Resources and International Sorghum and Pearl Millet Program (INTSORMIL) in 1984. Its time to maturity is similar to other commercial hybrids in Honduras. No insecticides or nematicides were used. Conventional cultivation, fertilizer (90-30-30 kg NPK ha^{-1}) and herbicide (1.5 kg ha^{-1} Atrazine) practices were employed. 400 plants were sampled weekly, 25 from every sixth row with each plant separated by *ca* 10 m of rows. Plants were pulled out of the ground, and leaves were removed and examined (destructive sampling) for the presence of FAW larvae. Larvae were placed in 1 oz. plastic cups containing an artificial diet (Bio-Mix 9781, Bio-Serv., Inc.) and held at room temperature for moth or parasitoid emergence. Weekly samples were taken 2 June–4 August.

1983 – Study 2

Fall armyworm larval densities were estimated in small plots during 1983 at La Lujosa. Crops sampled were Catracho sorghum and Tusa Morada maize. Tusa Morada is commonly planted by subsistence farmers in southern Honduras. Cropping systems (treatments) evaluated were: sorghum and maize in pure stand, intercropped in alternate rows ('surco-alterno'), and mixed cropped in alternate hills ('golpe alterno') and in the same hill ('casado'). Treatments were arranged in a randomized complete block design with four replications. Rows were 5 m long and 0.8 m wide; plants were spaced 0.5 m apart with 10 rows $plot^{-1}$. The destructive sampling technique was used to sample all plants in the 5th and 6th rows and 4th and 7th rows, four and six weeks after planting, respectively. The sorghum plants were in the mid-whorl stage at the time of sampling. Larvae were handled as in Study 1. The percentage infestation data was subjected to arcsin transformations and analysis of variance, and means were separated by Student-Newman-Keuls test (Steel and Torrie, 1960).

1984 Study

Cropping systems evaluated during 1984 included (1) sorghum in pure stand (Figure 1A), (2) sorghum with a natural weed complex (Figure 1B), (3) sorghum with maize (Tusa Morada) as a trap-crop planted in the middle of the plot (Figure 1C) and (4) sorghum and maize planted in the same hill (Figure 1D). The sorghum used was a photoperiod-sensitive native variety, Liberal, belonging to the *caudatum-durra* group. This tropical sorghum does not initiate the reproductive stage until after the maize is mature. Each treatment plot was 40 × 48 m, arranged in a 4 × 4 latin square design. The total area of the experiment was about 3.4 ha located at the La Lujosa Experiment Station, Choluteca, Honduras.

Propachlor with Atrazine pre-emergence herbicides at recommended rates were applied with a tractor-mounted sprayer. Weeds were kept to a minimum by hoeing, except for the plots receiving no weed control. Sorghum and maize were hand-planted using a 'chuzo' (a traditional digging stick) on 11–15 June in rows separated by 0.8 m and plants by 0.5 m. The sorghum seeds were pre-germinated (overnight in water) and treated with methyl parathion, 48 EC, insecticide (5 ml 2 l^{-1} of water applied to 11.3 kg $^{-1}$ of seed for 5 min) to prevent damage by ants.

30 plants treatment $plot^{-1}$ were destructively sampled weekly to determine the percentage of plants infested with FAW larvae. No samples were taken from the three border rows on each side of the plots. Six plants were sampled at random from each of five rows separated by 10 rows. Larvae were handled as in Study 1. When parasitoids emerged,

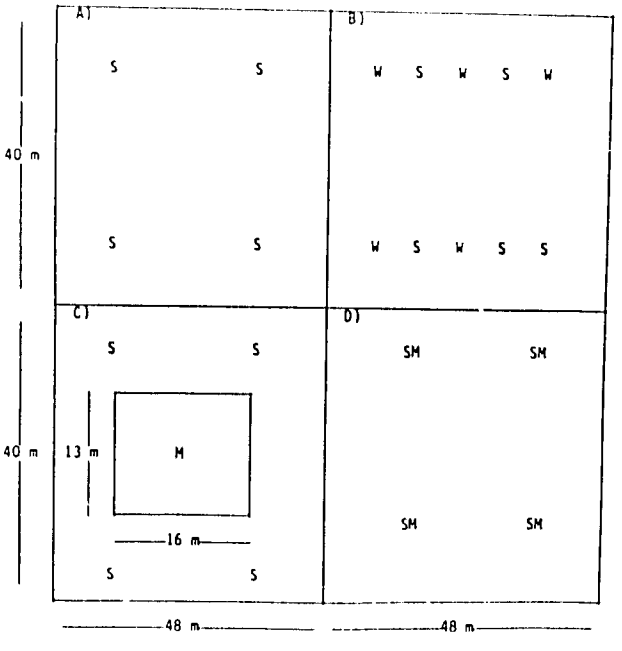

Figure 1 Sorghum-maize cropping systems, Choluteca, Honduras, 1984. A. Sorghum (S) pure stand, B. Sorghum with natural weed (W) infestation, C. Sorghum-maize (M) trap crop, D. Sorghum and maize (same hill).

the width of the head capsule of the dead FAW larvae was measured to determine the host instar at death. Head capsule measurements (width) of laboratory cohorts were used to identify each instar.

The percentage infestation data were subjected to arcsin transformation and sample dates were treated as subplots in the split plot analysis of variance for the 4 × 4 latin square. Means were separated by the Student-Neuman-Kuels test.

Results and discussion

1983 – Study 1

Fall armyworm larvae were present on Catracho sorghum 14 days after planting, infesting 8% of the plants (Figure 2). The percentage of plants infested, a measurement used in Honduras to determine the need for control measures, increased to a peak in late June and then decreased until 4 August at which time (boot stage) the infestation was negligible. These data show that hybrid sorghum was infested with FAW larvae during the early whorl stages of development, thus the crop can support the development of two generations (23.4–24.5 days for development from egg to adult on sorghum at 27°C according to Castro, unpublished data) of this lepidopterous pest during the first growing season in southern Honduras. It is apparent that the percentage of hybrid sorghum plants infested with FAW larvae declined as the host plants developed to maturity.

A nematode (Mermithidae) was present throughout the first growing season and parasitized up to 65% (mean, 22%) of the FAW larvae collected on sorghum (Figure 2). Other parasites included *Chelonus insularis* (Cresson) (Braconidae), which parasitized about 10% of the FAW larvae, and several unidentified tachinids which were present late in the first growing season and generally parasitized less than 10% of the larvae. *Chelonus* parasites have been the most frequently encountered parasites of FAW in many areas of Central America (Ashley, 1979), whereas the literature is lacking on parasitization of FAW by nematodes. Parasitization by nematodes increased as the FAW larval infestation increased and fell when the larval infestation declined. This observation may represent a numerical response or the nematode could be univoltine, reproducing soon after the onset of the rainy season.

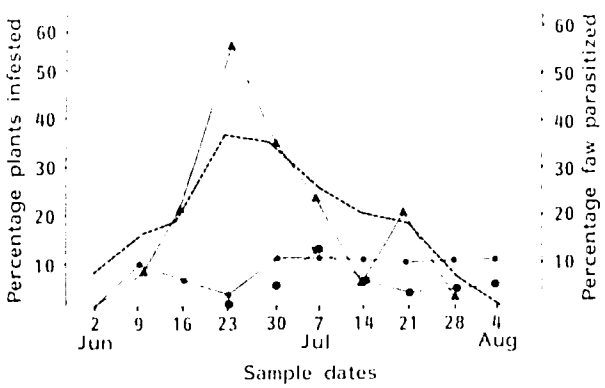

Figure 2 Fall armyworm larval infestation (percentage plants infested) on Catracho sorghum and incidence of FAW larval parasitization by nematodes, Choluteca, Honduras, 1983: - - - -, FAW larvae; ★, *Chelonus insularis*; ●, tachinids; ▲, mermithids

Further studies are needed to substantiate these observations.

1983 – Study 2

In pure crop stands, FAW infestation was significantly (P=0.05) greater on maize than sorghum, thus indicating maize as the preferred species (Table 1). Preference for maize was maintained throughout the different cropping systems except for multicropping in 'golpe alterno', where FAW infestations on sorghum increased significantly to a level comparable with and not significantly different from maize (Table 1). Infestations on maize were comparable in all systems, although multicropping maize in the 'casado' system with sorghum produced lower FAW infestations when compared with pure stand maize.

Fall armyworm infestations on sorghum differed between cropping systems which suggests that maize tended to influence FAW densities on sorghum in some of the cropping systems. The FAW infestation on sorghum when intercropped in 'surco alterno' with maize was comparable with pure stand sorghum; maize apparently did not significantly influence FAW densities on sorghum in this system. Similarly, FAW infestations on sorghum in the 'casado' system were not significantly different from sorghum in pure stand. However, as observed with maize, infestations on sorghum in 'casado' were lower than infestations on sorghum in pure stand. The tendency towards lower FAW densities on both species in the 'casado' system may be related to the closely growing species having a confusing effect (Tahvanainen and Root, 1972) on the moth's host-finding ability, which would result in less attraction of ovipositing moths to the general area. The FAW infestation on sorghum when multicropped in 'golpe alterno' with maize was significantly greater than in sorghum planted alone and with maize in 'surco alterno' and suggests that maize significantly influenced FAW densities on sorghum in the 'golpe alterno' system. Moths may have been attracted to and oviposited more frequently on maize growing in hills adjacent to sorghum and higher FAW infestations on sorghum may have resulted from larval dispersal from adjacent maize plants which were 0.5 m away. This phenomena was not apparent in 'surco alterno' intercropping where sorghum plants were farther away (0.8 m) from adjacent maize plants.

Intercropping maize and sorghum influences

Table 1 Percentage plants infested with fall armyworm larvae in five different cropping systems. Choluteca, Honduras, 1983. (Mean for two sample dates)

Planting system[1]	Sorghum (Catracho)	Maize (Tusa Morada)
Alternate hill ('golpe alterno')	38.9 aA[2]	37.0 aA
Alternate row ('surco alterno')	38.9 bB	37.9 aA
Monoculture	26.4 bcB	34.5 aA
Same hill ('casado'	19.4 cB	31.1 aA

[1]Sorghum and maize planted in alternate hills, 'golpe alterno'; both crop plants in same hill, 'casado'
[2]Means in a column followed by the same lower case letters and in a row by capital letters are not significantly different at P = 0.05 by Student-Neuman-Keuls' test

FAW infestation on the sorghum component. The 'casado' system tends to minimize FAW numbers on both maize and sorghum. This positive effect may partially explain why 'casado' planting is practised (by tradition) by some subsistence farmers, even though yields of both maize and sorghum are lower than when planted in other spatial arrangements. Multicropping maize and sorghum in 'gelpe alterno' is a common practice on rocky hillsides. However, this spatial arrangement tends to induce higher-than-normal FAW pressure on sorghum and may enhance its natural selection for host-plant resistance. Based on this observation, studies on host-plant resistance of Honduran sorghums to FAW have been initiated.

1984 Study

Fall armyworm infestations of cv. Liberal sorghum in the cropping systems treatment plots occurred from 28 June (day 15 post-planting) to September 4 (day 83 post), although sampling was continued until early November (Figure 3). This native sorghum does not initiate floral differentiation until early October. Thus, the plants were still in the whorl stage seven weeks after FAW infestation on both sorghum and maize had declined. This may indicate a change in plant quality for attractiveness to FAW for oviposition or for larval feeding and development, or the population on the plants may have been brought under control by natural enemies;

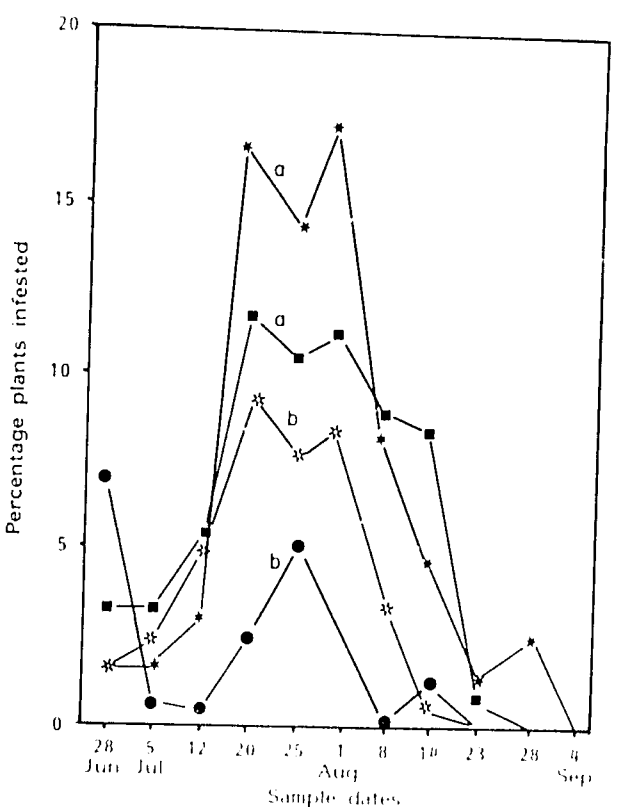

Figure 3 Fall armyworm larval infestation (percentage plants infested on sample dates) on Liberal sorghum in different cropping systems, Choluteca, Honduras, 1984. Seasonal population means (+ SEM) for treatments (calculated from samples on indicated dates and depicted with lines with different signs) with the same letter are not significantly different at $P = 0.05$ level by Student-Neuman Keuls' test. ■, sorghum (7.0 ± 3.9); ●, sorghum and weeds (2.5 ± 2.4); ★, sorghum and maize trap crop (7.2 ± 6.7); ✳, sorghum and maize; same hill (4.6 ± 3.2)

both possibilities need to be investigated. Since the FAW was still observed in the area infesting adjacent fields of younger maize and sorghum (Castro, personal observations), it appeared that the moths preferred the younger plants for oviposition. Pitre *et al.* (1983), however, reported that older sorghum plants had more FAW egg masses on the leaves than younger sorghum plants and discussed this crop/age preference by the insect in relation to survival significance in nature. Hanaway (1966) reported that morphological changes in maize phenology are associated with changes in the biochemical composition of plant tissues: the levels of N, P and K declined in maize leaves as they matured. The biochemical composition of sorghum may be correlated with FAW oviposition responses but this relationship needs to be investigated. In other studies related to plant age versus insect feeding, FAW larval consumption was reported to be 24% lower on maize in stages 1–2 (early vegetative) than in stages 3–4 (late vegetative) (Barfield and Ashley, 1987). This observation on FAW feeding on maize also may be associated with the biochemical position of the plants. Additional work is required to establish why the FAW population on sorghum and maize fell sharply in the second growing season in southern Honduras.

Sorghum with weeds and sorghum with maize in the same hill had lower infestations than sorghum planted alone or sorghum with the maize-trap crop (Figure 3). The treatment × date interaction was not significant, indicating that differences between treatments remained similar for all the sample dates. The cropping system that sustained the lowest infestation of FAW larvae on sorghum was that involving the natural weed complex. Plants in these plots appeared to be stressed as indicated by their yellow-green leaf color, indicative of nitrogen stress. This may have had an influence on the plant's attractiveness to FAW moths and thus the sorghum was not infested as heavily as sorghum in the other systems. Van Huis (1981) reported that FAW moths laid more eggs plant^{-1} on fertilized than on unfertilized sorghum. In our plots the strong competition of weeds with sorghum may have been responsible for nutritional changes in the sorghum that made it less attractive to FAW moths. This insect/host plant relationship needs to be investigated.

Fall armyworm moths have been reported to oviposit more on maize than on sorghum, even when the two crop plants are interplanted (Sifuentes, 1967, Van Huis, *ibid.*). This host preference by the FAW was expressed in the results of our 1983 Study 2, where larval densities in different sorghum maize multicropping and intercropping systems were higher on maize than on sorghum. Another possible cause for higher infestations of FAW larvae on and more damage to the maize crop may be related to the ability of the larvae to colonize maize more readily than sorghum.

The possibility of using a maize trap crop in the sorghum maize production system where FAW infestations could be concentrated on the preferred maize, thereby allowing control measures to be applied to the small trap crop areas, was tested in the 1984 study. The mean infestation of FAW on sorghum in the sorghum-maize trap crop system was significantly higher ($P = 0.05$) when measured over all sampling periods, than on sorghum in the other treatments, except for sorghum in monocul-

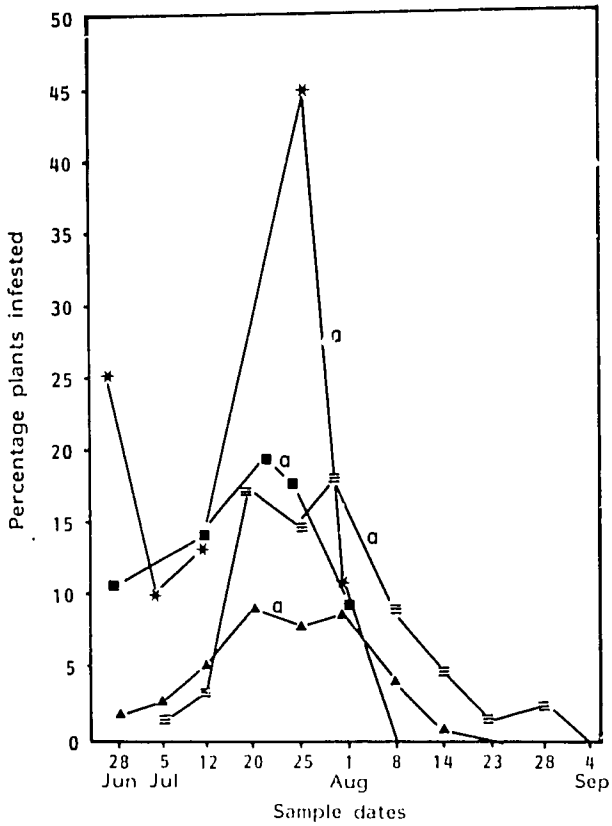

Figure 4 Fall armyworm larval infestation (seasonal percent plants infested ± SEM) on Liberal sorghum and Tusa Morada maize, Choluteca, Honduras, 1984. Seasonal population means for treatments (calculated for samples on indicated dates and depicted with lines with different signs) with the same letter are not significantly different at $P = 0.05$ level by Student-Neuman-Keuls' test. (Only significant difference on sample dates was observed on 7/25 when more larvae were in the maize trap crop than other treatments.) Trap: ★, maize (20.8 ± 14.8); ≡, sorghum (7.2 ± 6.7). Same hill: ■, maize (13.8 ± 4.4); ▲, sorghum (4.6 ± 3.2)

ture (Figure 3). It appears that FAW moths were strongly attracted to the maize in the middle of the whole plot for oviposition and from there the larvae dispersed to sorghum plants in adjacent areas. First instar larvae of FAW have the tendency to move to high points on the plant and, from there, disperse by means of silk threads blown by the wind (Morrill and Greene, 1973). Also, the presence of larvae in the whorl of maize plants may deter oviposition on the heavily infested maize plants, resulting in an increase in oviposition on the nearby sorghum. Gross (1984) found that maize plants treated with aqueous homogenates of FAW larvae deterred oviposition by this species. He suggested that semiochemicals of FAW larvae and/or their by-products may be responsible for inducing FAW females and to a lesser extent newly emerged FAW larvae to seek uncontaminated sites for oviposition and establishment, respectively.

Infestation of FAW on maize in the same hill with sorghum or on maize in the trap crop plots (Figure 4) were not significantly different from that on sorghum, and although there were substantially more larvae on maize than on sorghum in both systems, the differences were not significant in this study. The small size and configuration of the trap-crop test plot was inadequate to effectively evaluate management of FAW larval populations, but other spatial arrangements, i.e. different placement of the maize trap crop and increased test-plot size may prove to be effective in eliminating some of the problems encountered in the studies reported herein.

The application of a maize trap crop for monitoring FAW in sorghum/maize cropping systems in Honduras is ecologically practical and should be further investigated. Particular attention should be given to the distance the two crops are separated in the field to minimize the effects of FAW larval movement from maize to sorghum.

In this 1984 study, *C. insularis* parasitized 15% of the FAW larvae collected on 28 June, killing larvae in the fifth (62%) and fourth (38%) instars. A mermithid endoparasitic nematode parasitized FAW larvae collected on the foliage throughout most of the first growing season, with parasitization as high as 71%, apparently influenced by rainfall (Figure 5). The proportion of FAW larvae parasitized by nematodes was positively and highly correlated (r=0.93) with average rainfall for each week before the sampling date. Rain splashes transfer nematodes from the soil onto the plants. The nematodes killed FAW larvae principally in the fifth instar (59%), but also in the fourth (26%) and sixth (15%) instars. The mean number of nematodes emerging from a parasitized FAW larvae was five (SD ± 3, with range 1–18). Investigations are needed to determine the impact of this parasite on seasonal populations of the FAW, and the influence of certain insecticide/nematicide and cultural practices on its prevalence and effectiveness.

Differences in parasites present in 1983 and 1984 (i.e., parasitization by the nematode was low in July 1983 but high at that time in 1984) could be due to endogenous rhythms, the host plant of the FAW larvae which in 1983 was a short-season hybrid and in 1984 was a photoperiod-sensitive native sorghum, or rainfall.

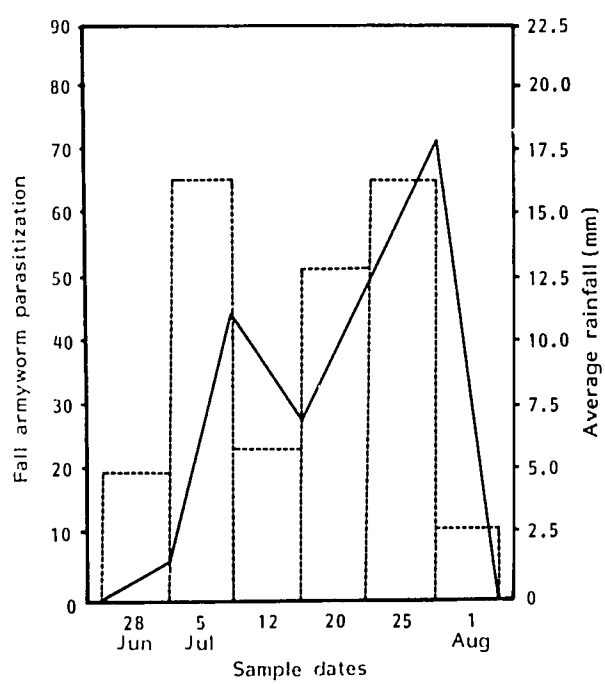

Figure 5 Percentage fall armyworms parasitized by nematodes and average rainfall (mm), Choluteca, Honduras, 1984: ——, fall armyworm parasitization; ----, average rainfall; r = 0.93, n = 7

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