Validation of new agronomic and plant protection technologies in intercropped sorghum and maize in southern Honduras

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Abstract. Agronomic and plant protection technologies were evaluated on intercropped sorghum and maize in southern Honduras during 1990. In this study crop production treatments were: 1) conventional practices (using landrace sorghum), 2) conventional practices plus an improved sorghum cultivar, 3) farmer's conventional practices plus the improved sorghum cultivar, corn and sorghum seed treatment, and weed control, and 4) same as treatment 3 plus nitrogen fertilizer. Planted sorghum seed lost to pathogens in plots with landrace sorghum (1%) was significantly lower than that in plots with the untreated improved sorghum cultivar (10%), but was not different from that in plots with the treated improved sorghum cultivar (pooled mean=3.5%). Significantly more sorghum seeds were removed by arthropods from plots with landrace sorghum (9%) than from plots with untreated seed of the improved sorghum cultivar (0.6%). Levels of maize seed damaged (0.6-3.2%) or removed (0-0.3%) by arthropods were similar in all treatment plots. Fall armyworm (FAW) larval infestation was significantly higher on planted maize with conventional practices than with conventional practices plus the improved sorghum cultivar, seed treatment and weed control 23 days after planting: whereas infestations on sorghum did not differ among treatments on any sample date. FAW larval survival was similar in all treatments, but a hymenopterous parasite was more active in plots with conventional practices than in plots with conventional practices plus the improved sorghum cultivar, seed treatment and weed control. Yield increases with improved technology inputs into sorghum and maize varied from 17 to 60% and 0 to 22%, respectively. Additional validation of these technologies in large scale fields is needed to confirm these results.

Key words: Intercropping, plant protection technology validation.

Resumen. Tecnologías agronómicas y de protección de plantas fueron evaluadas en sorgo y maíz intercalado en el sur de Honduras en 1990. Los tratamientos fueron: 1) práctica convencional (uso de razas nativas de sorgo), 2) prácticas convencionales más un cultivar de sorgo mejorado, 3) prácticas convencionales más el cultivar de sorgo mejorado, semilla de maíz y sorgo tratadas, y control de malezas, y 4) lo mismo que el tratamiento 3 más fertilizante nitrogenado. La pérdida de semilla de sorgo por patógenos en sorgos nativos fue significativamente más bajo (1%) que los lotes de sorgo mejorado no tratados (10%), pero no fueron diferentes en sorgo mejorado tratado (media = 3.5%). Significativamente más semillas de sorgo fueron removidas por artrópodos de los lotes con semillas de sorgo nativo (9%) que de lotes de sorgo sembrados con cultivares mejorados no tratados (0.6%). Los niveles de daño en semillas de maíz (0.6-3.2%) o semilla removida por artrópodos (0-0.3%) fueron similares en todos los tratamientos. La infestación por larvas de cogollero fue significativamente más alta en maíz con prácticas convencionales que con prácticas convencionales más el cultivar mejorado de sorgo, semilla tratada y control de malezas a los 23 días después de siembra; mientras que las infestaciones de cogollero en sorgo no fueron diferentes entre los tratamientos en ninguna de las fechas de muestreo. La sobrevivencia de larvas de cogollero fue similar en todos los tratamientos, pero un parasito himenóptero fue más activo en lotes con prácticas convencionales que en lotes con prácticas convencionales más cultivar de sorgos mejorados, semillas tratadas y control de malezas. Los incrementos en rendimientos con el uso de tecnología mejorada en sorgo y maíz varió de 17 a 60% y 0 a 22% respectivamente. Validación adicional de estas tecnologías a gran escala es necesaria para confirmar estos resultados.

Palabras claves: Intercalado, validación de tecnología de protección de plantas.

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INTRODUCTION

Sorghum, *Sorghum bicolor* L. Moench and maize, *Zea mays* (L.), are two of the most important crops in Honduras (Secretaría de Planificación, 1987). Environmental conditions in southern Honduras are characterized by erratic precipitation, high temperature, and low soil fertility. This conditions are unfavorable for maize production which is commonly lost to drought. However sorghum is better adapted and approximately 82% of the sorghum area in this region is intercropped with maize (López, 1990), therefore if the maize crop is lost, the farmer substitutes sorghum for maize to feed their animals and family (DeWalt and DeWalt 1987).

Landrace sorghum and local early maize populations are widely planted in southern Honduras (Pitre, 1988). Between 1983 and 1988, 52% of sorghum produced in Honduras was grown in the southern area of the country; 95% of this was represented by local landraces grown on small farms (Ministerio de Economía, 1990). Average sorghum yield per hectare declined from 0.93 metric tons in the 1970s to 0.85 in the 1980s, with an annual rate of decrease of 2.3% (Garcia *et al.*, 1988; Ministerio de Economía, 1990). Reduction in yield is generally attributed to several factors, including increased insect pest population and cultivation of more marginal lands.

Weed control would be expected to benefit the crops by reducing plant competition, thus increasing yield. However, populations of important insect pests, like the fall armyworm, *Spodoptera frugiperda* (J.E. Smith) (Andrews, 1988; DeWalt and DeWalt, 1982; Pitre, 1988) are present in greater quantities on maize and sorghum plants in plots without weeds than in plots with weeds (Castro, 1990; Portillo *et al.*, 1991).

The inherent low yield potential of local landrace sorghum cultivars, regionally called "maicillo criollo", limits yield increases even when crop production conditions are favorable. Improved landrace sorghum cultivars have shown a yield advantage of 31% over their "maicillo criollo" ancestors under the same no-input conditions in farmers' fields (Meckenstock, 1988; Gómez, 1994). However, soil inhabiting insects, like wireworms, are important pests (Trabanino *et al.*, 1990), and can account for up to 10% sorghum seed loss in some areas in Honduras (Portillo *et al.*, 1994a). Furthermore, ants and millipedes contribute to the removal of seeds after sowing (Carroll and Risch, 1984; Trabanino *et al.*, 1990). Seed treatment with insecticides can considerably reduce seed loss by these arthropods (Trabanino *et al.*, 1987; Portillo *et al.*, 1994b).

The objective of this preliminary study was to evaluate the effectiveness of different agronomic and plant protection technologies on the overall performance of intercropped sorghum and maize on subsistence farms in southern Honduras.

MATERIALS AND METHODS

The study was conducted at La Coyota which is located in the foothills at 52 m above sea level in the Department of Valle in southern Honduras (coordinates ca. 13° 31' N, 87° 43' W) during May-August 1990. The steep slopes and rocky soils of the fields prevent the use of mechanical equipment for soil preparation; however, ox-pulled plows may be used in some fields. Generally, the farmers in this area do not have money to purchase chemicals, but they use conventional subsistence crop production practices. Both sorghum and maize are planted simultaneously. Maize matures early and is harvested by mid-August, while the local landrace sorghum populations are sensitive to photoperiod and do not bloom until the day length becomes shorter (mid-October to early November) and are harvested in January (Meckenstock, 1988; Rosenow, 1988).

Four farms, each representing a replicate, were randomly selected and fields measured 900 m^2 (plot size = 225 m^2). One field was planted on May 22, one on June 1, and two on June 2. Sorghum and maize were sown simultaneously in alternate hills on 70-90 cm rows; the distance between hills was approximately 50 cm.

Four experimental treatments (T) were established on each farm: T1) represented conventional cropping practices for this area, including landrace sorghum and maize, no weed control (except for slash and burn prior to planting), no fertilizer, and insecticide sprays using farmer's decision (hereafter refered to as "conventional practices"), T2) same as T1, except that the improved sorghum cultivar (San Bernardo III × TAM428) (Meckenstock *et al.* 1991) was planted, T3) same as T2, except that sorghum and maize seeds were treated with furathiocarb (Promet 400 CS®) (CIBA-GEIGY Limited 1988) at 10 g ai/kg maize seed and 20 g ai/kg sorghum seed and manual weed control was included as needed, and T4) same as T3, except that 58 kg of nitrogen/ha were applied 24±1 days after planting and insecticides were applied only when a threshold of 40% of the plants were infested with fall armyworm (Andrews, 1989).

Preemergence seed samples were taken by removing all sorghum and maize seeds from randomly chosen hills at ten sample sites in the two middle rows of each plot on day four after planting. Data were recorded for percent seed germination and percent seeds damaged by insects. Farmers in southern Honduras plant an average of 12-15 sorghum seeds/hill (DeWalt and DeWalt, 1982) and three to five maize seeds/hill (Sequeira, 1987). Since the number of seeds planted per hill was not accurately controlled, percentages were estimated from the actual number of seeds found at sampling time. Seed germination rates determined in incubators in the laboratory (n= 100 seeds, 2 replications) for seed used on each farm were compared with the percentage of seed germinated in the field. If germination percentage of a particular treatment or crop was higher in the field than in the laboratory, the difference between the two was considered to be due, in part, to seed removal by arthropods in the field.

Whole plant, destructive samples were taken at random from each plot, and included 30 sorghum and 30 maize plants, to determine insect infestation. Numbers of fall armyworm larvae on each sampled plant were recorded 9, 16, 23, 30, and 44 days after planting. Larvae collected in each treatment plot were immediately confined in 29.6 ml plastic cups (1 larva per cup) containing pinto bean artificial diet (Perkins, 1979). The cups with larvae were placed inside a box containing blue ice (Rubbermaid®, Forestry Suppliers, Inc. Jackson, MS 39284-8397) and transported to the laboratory at the Panamerican School of Agriculture, Zamorano, Honduras. Parasites emerging from the larvae were identified and recorded for each treatment and crop. Treatment samples were combined for all farms.

The average percentage of ground area covered by weeds in each plot 40 days after planting was determined visually by estimating the ground area covered in every row of each plot. Sorghum and maize yield data were taken from the remaining plants in each plot after the destructive plant samples for fall armyworm larvae. One farm was lost to drought and one farmer harvested early, thus sorghum yield data were recorded in only two fields, whereas maize yield data were recorded on three of the four farms. Grain moisture was measured at harvest using a Steinlite electronic tester (Seedburo Equipment Co.®), and yields were corrected to 12% moisture (Paul, 1990) prior to statistical analysis.

Except for larval parasitization and sorghum yield data, statistical analysis consisted of two-way ANOVA and means were separated using Tukey's (Honest Significant Difference) mean separation test (SAS Institute, 1985; Steel and Torrie 1980). Percentage data were transformed by arcsin of square root prior to analysis (Steel and Torrie, 1980). Larval parasitization data were analyzed by Chi-square test of homogeneity in a 3 (causes of mortality) × 4 (treatments) contingency table and proportions were compared by contrasts using a post hoc multiple comparison test (Marascuilo and McSweeney, 1977; Daniel, 1990). Low sample sizes for sorghum yield data caused heterogeneous variances among treatments, thus Friedman's two-way ANOVA by ranks analysis was used (Daniel, 1990).

RESULTS AND DISCUSSION

The pooled mean ±SD (across treatments and replications) number of sorghum and maize seeds recovered from the preemergence field samples was 63.2 ±11.6 and 38.1 ±2.8, respectively. The relatively high number of sorghum seeds sampled in the field allows reasonable comparisons between the percentage of germinated seeds in the field verus the laboratory (100 seeds were used for the laboratory tests), and justifies our method of calculating missing seeds as explained in the materials and methods section. Seed removal by arthropods was not a problem for maize in any of the treatments, however caution should be taken when comparing the percentages of missing maize seeds as lower number of maize seeds were sampled in the field as compared to the laboratory.

Sorghum and maize germination rates among the treatments were not different in the field (Table 1). Seed germination in the laboratory was similar (no statistical analysis performed) for each cultivar (mean ±SD): maize, untreated = 96 ±1%, treated = 97 ±1%; (San Bernardo III × TAM428) sorghum, untreated = 90 ±1%, treated 90 ±3%; and untreated landrace sorghum = 90 ±2%.

Table 1. Mean ±SE sorghum and maize seed survival under different treatments five days after planting in the field in southern Honduras, 1990.

Treatment[1]	% Germinated seed		% Non-germinated seed[2]		% Seed damaged by insects[3]		% Missing seed[4]	
	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum	Maize	Sorghum
T1, Conventional practices	93 ±1.7a	90 ±0.0a[5]	4.5 ±0.7a	1.0 ±1.0b	2.4 ±1.7a	0.0 ±0.0a	0.0 ±0.0a	9.0 ±1.0a
T2, Conventional practices plus improved sorghum cultivar	86 ±5.0a	87 ±1.9a	11.0 ±5.2a	10.0 ±2.7a	3.2 ±2.3a	2.3 ±1.4a	0.3 ±0.3a	0.6 ±0.4 b
T3, Same as T2 plus seed treatment with insecticide	91 ±2.6a	90 ±0.0a	6.4 ±2.7a	2.0 ±1.1ab	2.5 ±1.0a	1.3 ±0.9a	0.1 ±0.1a	6.5 ±2.0ab
T4 = Same as T3 plus N	85 ±3.0a	88 ±1.9a	13.8 ±2.4a	5.3 ±4.1ab	0.6 ±0.6a	0.7 ±0.4a	0.0 ±0.0a	5.8 ±2.0ab

[1] Seed treated with furathiocarb at a rate of 10 and 20 g ai/ kg of maize or sorghum seed, respectively.
[2] Appears healthy but did not germinate.
[3] Wireworms (Coleoptera: Elateridae, Tenebrionidae).
[4] Presumably removed by ants and millipedes.
[5] Means followed by the same letter within the same column are not significantly different (P=0.05) by Tukey's (HSD) mean separation test (Steel and Torrie 1980).

The lower seed germination in the field was related to external factors such as damage by pathogens. Surprisingly, the percentage (10 ±2.7) of non-germinated seeds in plots planted with the improved (San Bernardo III × TAM 428) untreated sorghum seed was significantly higher than that in plots planted with landrace sorghum seed (1 ±1.0) (Table 1). Plots planted with treated improved sorghum seed had similar percentages (2 ±1.1 vs 1.0 ±1.0) of non-germinated seed as plots planted with untreated landrace sorghum. It is possible that seed of the improved sorghum cultivar (San Bernardo III × TAM428) is more susceptible to soil pathogens, . but treatment with furathiocarb prevented damage by pathogens in plots planted with this sorghum seed. The authors are not aware of literature that supports this idea. However, furathiocarb is a carbamate insecticide that belongs to the chemical group of thiocarbamates, a close relative of the dithiocarbamates, where most currently used and effective fungicides are found (Agrios, 1988).

There were no significant differences among the treatments in the percentage of sorghum or maize seeds damaged by insects (Table 1). Soil inhabiting insect pests (no quantitative infestation data recorded in this study) may have been in low numbers at the test sites, however wireworms (Coleoptera: Elateridae, Tenebrionidae) caused most of the observed seed damage by insects. Trabanino *et al.*, (1990) reported damaging levels of wireworm larvae in intercropped sorghum and maize fields in the foothills, as well as on the coastal plains in southern Honduras.

The percentage of maize seeds missing was not significantly different among treatments (Table 1). However, there were significantly more missing seeds (9.0 ±1.0 vs 0.6 ±0.4) in plots planted with landrace sorghum than in plots planted with untreated (San Bernardo III × TAM428). The percentage of sorghum seeds missing in plots planted with treated seed of (San Bernardo III × TAM428) was only somewhat lower than that in plots planted with the landrace sorghum (Table 1). San Bernardo III × TAM428 sorghum seed may have some antixenotic effect that detered seed removal by ants, millipedes or other arthropods. However this possible antixenotic effect may have been masked by coating the seed with insecticide. It is also plausible that the insecticide itself attracted more arthropods. Except for the benefit of an apparent reduction in seeds lost to seed pathogens, results of this study do not show significant advantages in the use of furathiocarb as seed treatment for insect control. However, previous studies have shown that under intensive insect pressure furathiocarb seed treatment significantly reduced seed loss by soil inhabiting insects (Trabanino *et al.*, 1987; Portillo *et al.*, 1994b).

Except for plots with treatment 3, fall armyworm larval infestation on maize peaked 23 days after planting in all treatment plots (Figure 1A). At that time the number of larvae per plant was highest in plots with conventional practices, but only significantly higher than the infestation in plots planted with furathiocarb treated maize seed plus weed control (T3). Weed coverage ranged from 0 to 40% (mean=12%) in plots without weed control (T1 and T2) and from 0 to 3% (mean=2%) in plots with weed control (T3 and T4). Additional weed control (T3 and T4 plots, 38 days after planting) and insecticide application (all treatments) were needed only on one of the four farms. Nitrogen was applied in T4 after the fall armyworm population peaked. Conditions in plots with the highest levels of crop production technology (T3 and T4) were similar up to that time, thus one would expect similar insect population densities in both treatment plots prior to application of the fertilizer. Within that time period, although T4 plots were infested with higher numbers of fall armyworm larvae than T3 plots, this difference was not significant ($P \leq 0.05$).

Castro (1990) and Portillo *et al.* (1991) reported higher numbers of fall armyworm larvae on crop plants in plots with weed control than in plots without weed control. This effect, however, was not observed in the two treatments with the highest levels of crop production technology in this study. The systemic effect of furathiocarb in maize seedlings may have had a negative influence on fall armyworm establishment in plots receiving the systemic insecticide treatment. This would suggest that the systemic insecticide protected the crop plants during seed germination, seedling development and early whorl stages. Fall armyworm population density on sorghum did not differ among the treatments at any sample date, and were in general much lower than the treatment threshold (Figure 1B).

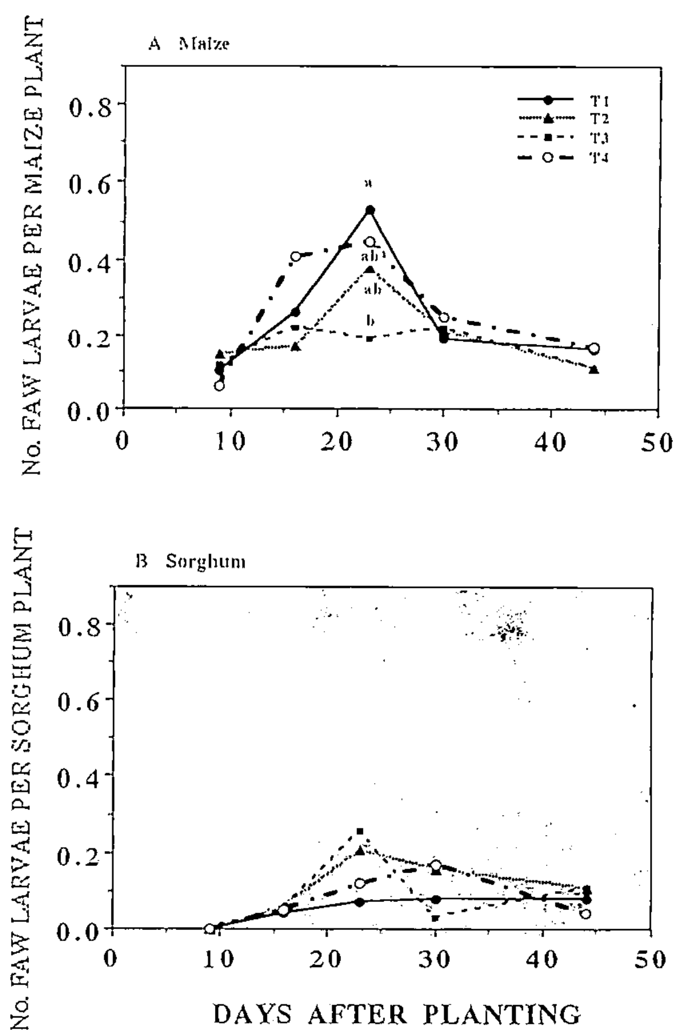

Figure 1. Population density of fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), on maize (A) and sorghum (B) in intercropped field plots treated with different technological inputs in southern Honduras, 1990. T1 = conventional practices, T2 = conventional practices plus improved sorghum cultivar, T3 = conventional practices plus improved sorghum cultivar, seed treatment with insecticide and weed control, and T4 = same as T3 plus insecticide application using a FAW threshold (40% infestation) and nitrogen application. Line points followed by the same letter are not significantly different ($P \leq 0.05$) by Tukey's (HSD) mean separation test (Steel and Torrie, 1980).

Parasitization. Two parasites, an unidentified wasp [tentatively identified as *Chelonus insularis* (Cresson), Hymenoptera: Braconidae] and a nematode (*Hexamermis* sp. Nematoda: Mermithidae) contributed to fall armyworm larval mortality in this study.

Fall armyworm larvae collected on maize 9, 23, and 30 days after planting or on sorghum 23 days after planting had a heterogeneous proportion of larvae parasitized by both organisms or not parasitized among the treatments (Figure 2). There were no significant differences among treatments when the percentages of surviving larvae were compared.

The data indicate that an equal number of larvae survived in each treatment after the effects of both parasites were taken into account. Thus, parasites did not appear to have an influence on fall armyworm infestations in this study. It is interesting to note, however, that fall armyworm larvae collected on maize 23 days after planting in plots treated with conventional practices had a significantly greater percentage of parasitization by the hymenopterous parasite than larvae collected in plots with conventional practices plus the improved sorghum cultivar, seed treatment with insecticide and weed control (Figure 2C). The differences in weed cover within treatment plots (12%, T1; 3%, T3) may have been responsible for this observed increase in parasitization, however, this was not documented.

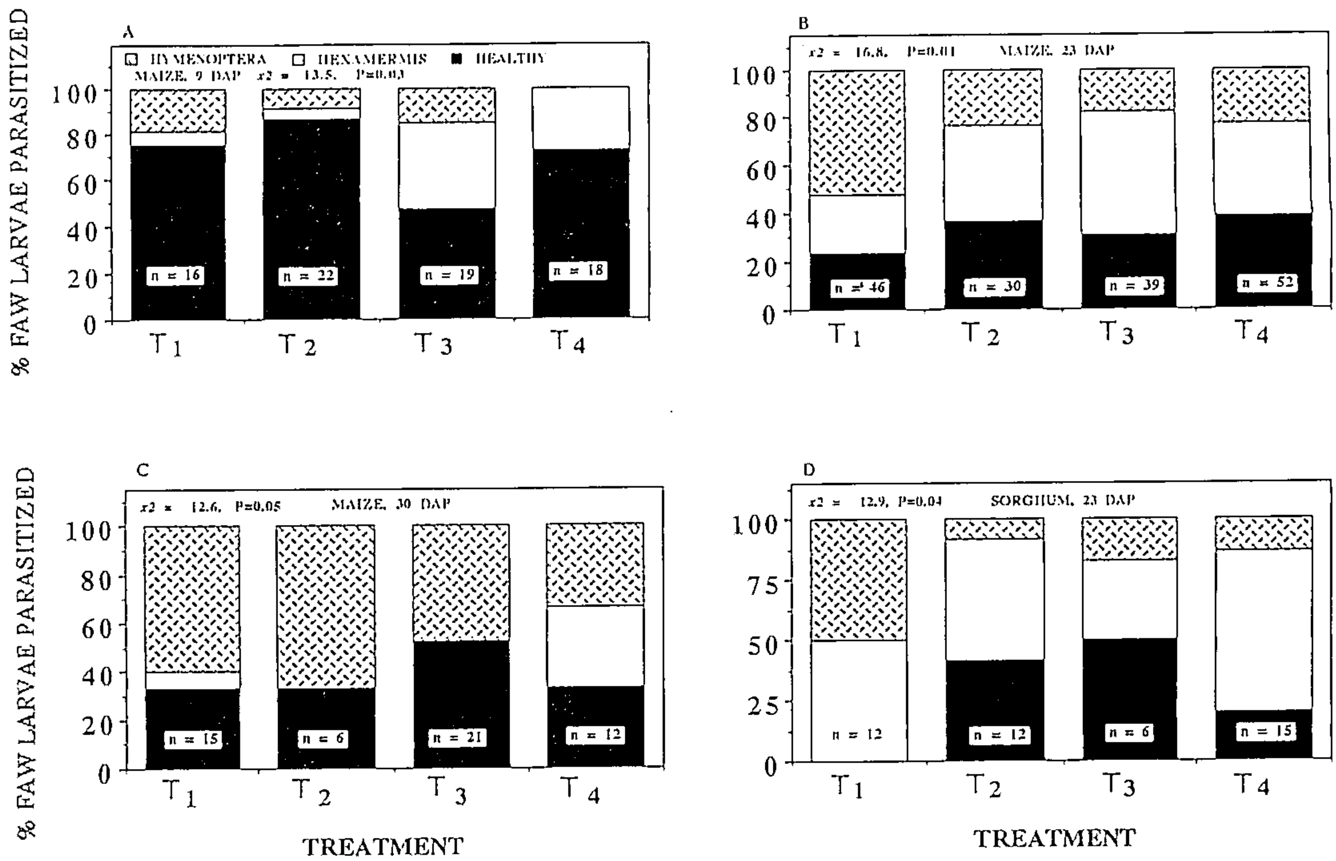

Figure 2. Parasitization and survival of fall armyworm (FAW), *Spodoptera frugiperda* (J.E. Smith), larvae at various times during the growing season on intercropped maize [(A, 9 days after planting (DAP), n=75 larvae, B, 23 DAP, n=167 larvae, C, 30 DAP, n=54 larvae) and sorghum (D, 23 DAP, n=45 larvae) in field plots treated with different technological inputs in southern Honduras, 1990. T1 = conventional practices, T2 = conventional practices plus improved sorghum cultivar, T3 = conventional practices plus improved sorghum cultivar, seed treatment with insecticide and weed control, and T4 = same as T3 plus insecticide application using a FAW threshold (40% infestation) and nitrogen application. Figures with a significant ($P \leq 0.05$) Chi-square value indicate that proportions of the different factors were not homogeneous among the treatments (Daniel 1990).

C. insularis and *Hexamermis* sp. are the most common parasites found in maize in some areas of Honduras and are reported to cause fall armyworm larval mortality up to 57% and 25%, respectively (Wheeler *et al.*, 1989). The highest levels of fall armyworm parasitization (mortality) observed on a single date in this study were 69% by the hymenopterous parasite and 67% by *Hexamermis* sp. These data stress the importance of monitoring the effect of new technology inputs, like those tested in this study, on parasite populations.

Yield. There was a trend for increased yields with increased level of technology input into the intercropping production system, but the differences were not significant for either sorghum or maize (Figure 3). However, in this study experimental power for yield data was reduced by a limited number of replications. The differences observed would be of economic importance if they were real. But the low insect pest population and weed infestation did not allow treatments to express maximum effects. The sorghum and maize yields observed in T4 plots were on average 48% and 22%, respectively, greater than the other treatments.

This was attributed, in part, to the application of nitrogen fertilizer. The cultivar (San Bernardo III × TAM428) with untreated seed appeared to have a higher yield (T2 = 17% greater) than the landrace cultivar. When treated seed of this cultivar were planted and weeds were controlled, this treatment yielded 46% more than the landrace. A further increase of 64% in yield was observed when seed were treated and weed control and nitrogen were applied in the system. Seed treatment and weed control practices, however, appeared to be of little importance on maize when yield was observed in plots with conventional practices, improved cultivar, seed treatment and weed control (Figure 3).

CONCLUSIONS

The present results indicate that with a low soil insect population, seed treatment with furathiocarb did not appear to be very important for maize production. Seed of (San Bernardo III × TAM428) may be more susceptible to soil pathogens and may benefit indirectly from chemical treatment by reducing seed loss to pathogens. This possible fungicidal effect needs confirmation in future studies as well as the effect of seed treatment with fungicides registered for this purpose. The low seed removal percentage in plots planted with untreated seed of (San Bernardo III × TAM428) indicated that this cultivar is less attractive to ants and other arthropods than the landrace sorghum. Plots with weed control (T3 and T4) had lower fall armyworm populations on maize than plots without weed control. This contrasts the observations reported by Castro (1990) and Portillo *et al.* (1991). However, chemical seed treatment was not a factor in the earlier studies. One might conclude that seed treatment with insecticide may have prevented a fall armyworm population increase in plots with seed treatment in the present study.

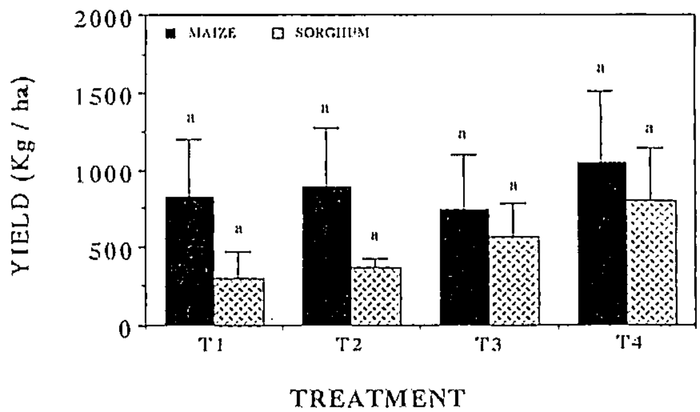

Figure 3. Mean ±SE maize and sorghum grain yield in intercropped field plots treated with different technological inputs in southern Honduras, 1990. T1 = conventional practices, T2 = conventional practices plus improved sorghum cultivar, T3 = conventional practices plus improved sorghum cultivar, seed treatment with insecticide and weed control, and T4 = same as T3 plus insecticide application using a FAW threshold (40% infestation) and nitrogen application. Yield variances of the different treatments were not significantly different ($P \leq 0.05$) by two-way ANOVA (maize) and Friedman's two-way ANOVA by ranks (sorghum) (Steel and Torrie 1980, Daniel 1990).

There was a numerical increase in yield corresponding to an increase in sorghum crop production technology input into the intercropping system. The relatively low insect and weed infestations in all treatments did not appear to have an adverse influence on yields. The low infestations allowed the maize and the improved sorghum cultivar (San Bernardo III × TAM428) to respond positively to nitrogen fertilization. High variability of yield data in on-farm trials (farmers conditions) is commonly observed. Thus, some researchers justify the use of much lower probability levels (e.g., P=0.25) in the analysis and interpretation of yield data (Gómez, personal communication). There were no differences in yield among treatments ($P \leq 0.05$); however, maize and sorghum yield data would have been significantly different among treatments at probability levels of P=0.23 and P=0.17, respectively. Therefore, development of recommendations as to the level of technology that should be incorporated into a crop production system would depend on economic analysis and the extent of risk that one is willing to take. The positive results observed in this preliminary investigation stress the importance of conducting additional validation studies and finally extending the benefits of these new agronomic and crop protection technologies to subsistence farming operations in southern Honduras and similar areas in the region.

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