DISCUSSION AND CONCLUSIONS

The accent of this study was to conduct a benchmark assessment of soybean stem fly, Melanagromyza sojae (Zhnt.) and their natural enemies under conditions similar to those practiced by the soybean farmers in the Chiangmai valley. The two limitations which were encountered during the conduct of this study were soybean replanting due to germination problems and the possible effects the routine pesticidal applications of the surrounding soybean and other vegetation had on the population dynamics of the insects in the experiment.

Sampling Soybean Stem Fly, Melanagromyza sojae (Zehntner) on Soybean

Sampling adult populations

The data presented in Table 2 and Figure 3 suggested that the population densities of adult stem flies were significantly more abundant in soybean monocultures kept weed-free throughout the season than weedy soybean monocultures or soybean/corn polycultures weedy or weed-free throughout the season ($p<0.01$). With the highest densities of 12.13 to 18.03 stem flies per 25 soybean plants in cropping systems which were either kept weed-free throughout the season or weed-free for a relatively longer period of time (four weeks after planting), and lowest densities of 4 to 9.2 stem flies per 25 plants in cropping systems where weeds were either allowed to grow throughout the season or weed-free for a relatively shorter period of time (two weeks after planting), a seemingly inverse relationship exists between stem fly densities and the length of time the plots weeded. The data also indicated that allowing weed growth during selected periods of the crop cycle resulted in lower M. sojae densities in both weedy monocultures and polycultures. This finding agrees with the generally accepted theory that ecosystems in which plant species are intermingled possess an associational resistance to herbivores in addition to the resistance of individual plant species as stated by Root (1973). According to the information obtained from these experiments, the soybean plants were being dispersed in a community of high spatial, biotic, and microclimatic complexity. These factors of mixed vegetation possibly work synergistically to produce an associational resistance to stem fly attack.

Altieri et al. (1981b) reported similar results that the herbivores Anticarsa gemmatalis (Hubner) and Nezara viridula (L.) developed higher population densities in weed-free soybean than in weedy soybean. This data also agrees with the conclusion given by Altieri (1982) relating to the population densities of Phyllotreta cruciferae Goeze and Brevicoryne brassicae (L.) in collard/bean cropping systems which were significantly reduced because the bean intercrops interferes with the pattern of perception of the crop by these invading insect pests thus making the crop less apparent. Altieri and Liebman (1986) also pointed out that differences in the structure of the crop canopy in tall maize/soybean and short maize/soybean plots appeared to affect the behavior of several groups of herbivores, with lower abundance of Japanese beetles due to shading of the soybean canopy by the taller maize plants. The conclusion could be drawn from this experiment that the presence of corn while allowing natural weed growth in the various soybean cropping systems could have resulted to a wide variety of microclimates which may not have only caused the difficulty of stem flies in locating soybean but also in remaining in them once they located them. This effect may have been compounded by the shading of the corn intercrop on soybean and may have caused the stem fly to evade these cropping systems. Thus, lower populations were counted in the weed-free polycultures and weedy monocultures and polycultures than the more simplified weed-free monocultures thereby conferring an associational resistance to soybean.

Sampling larvae and pupae populations

Tables 2 and 5 showed that highest immature stem fly density of 4.75 larvae and pupae per 10 plants was counted in soybean monocultures and soybean/corn polycultures kept weed-free for only four weeks after planting. But this was not statistically significantly different from number of larvae counted from soybean monocultures weed-free for only two weeks after planting, soybean/corn polycultures weed-free throughout the season, and soybean/corn polycultures weed-free for only two weeks after planting. The lowest immature stem fly density of 2.28 larvae and pupae per 10 plants which was recorded in soybean monocultures weedy throughout the season was statistically significantly different from all other cropping systems. These results suggested that less stem fly larvae can be found in the more weedy cropping systems.

Data in Table 4 and Figure 5 showed heavy fluctuations in percent infestations among the various cropping systems until the seventh week. The trend in percent infestation was decreasing in monocultures weedy throughout the season and weed-free for only two weeks after planting, and polycultures weed-free for only two weeks after planting and weedy throughout the season. It was also evident that percent infestation increased in monocultures kept weed-free throughout the season, monocultures weedy throughout the season, polycultures weed-free for only four weeks after planting and polycultures kept weedy throughout the season. However, results of dissection studies after soybean harvest indicated that there was more or less a hundred percent infestation in all cropping systems. There was a direct relationship between larval counts and percent infestation as shown in Figure 7 to 10 which was similar to that reported in Taiwan by Chiang and Talekar (1980).

The *Eurytoma* sp. was apparently the only parasitoid of *M. sojae* present. The rate of parasitization was highly variable throughout the season. No correlation was observed between larvae counts and percent parasitization. Although there were no statistically significant differences among the rates of parasitization related to cropping design, the results of the current experiment represented in Table 5 seem to be in agreement with those existing in literatures. Altieri et al. (1981) demonstrated that parasitization rates of Heliothis zea Boddie eggs by Trichogramma sp. were greater when the eggs were placed on soybeans next to corn and the weeds Desmodium sp., Cassia sp. and Croton sp., than on soybeans grown alone. This was possibly due to the emission of volatiles with kairomonal action. Similarly, in a study by Letourneau 1983 (quoted in Altieri and Liebman 1986) more parasitoids were found in the vegetationally diverse corn/bean/squash systems. Larval samples in polycultures showed an incidence of 59% parasitization to Diaphania hyalinata (Lepidoptera: Pyralidae) whereas monocultural larvae specimens were 29% parasitized. It was evident that potentially higher numbers of M. sojae were parasitized by naturally occurring Eurytoma sp. in the weedy plots than in the weed-free systems. It is also interesting to note that parasitization rates seem to be directly proportional to the density of weeds. This means that lesser parasitization rates were obtained in less weedy cropping systems than the more weedy cropping systems. This data agree with the conclusion given by Altieri et al. (1981a) relating to the lower parasitization rates of Heliothis zea eggs by the Trichogramma sp. when eggs were placed in soybeans grown alone than in soybeans grown with other plants. However, the rate of parasitization was observed to be lower when weed growth was not suppressed in cropping systems weedy throughout the season.

There seem to be no relationship between the number of larvae and adults with the rates of parasitization except in mononocultures and polycultures kept weed-free for only two weeks after planting and monocultures weed-free throughout the season as shown in Figures 12, 24, and 26. This finding suggests that decrease in stem fly numbers in weedy cropping systems compared to weed-free monocultures can be attributed to a complex of factors. It is probable that the presence of the naturally occurring parasitoid, Eurytoma sp. in these cropping systems is only one among these factors.

Predator Population Densities Assessment

The abundance of predators associated with *M. sojae* in different cropping systems are summarized in Table 7 to 12 and in Figures 27 to 32. Up to 10.11 natural enemies per 25 soybean plants were found in soybean monocultures kept weed-free for only four weeks after planting (Table 14, Column 4). There were no statistically significant differences among the means of natural enemies for the following tested: monocultures kept weedy throughout the season, weed-free for only two weeks after planting, weedy throughout the season and all polycultures designed. The total number of morphospecies of 6 in soybeans grown in weed-free monocultures was lesser as compared to a total of 7 morphospecies in soybean/corn polycultures weed-free throughout the season. This insect diversity in polycultures as reflected in the higher diversity indeces results for soybean/corn polycultures as compared to soybean monocultures is the result of increased spatial heterogeneity and complexity of polyculture cropping systems. The incorporation of corn and weed vegetation in soybean presumably increased the amount of food resources, therefore enhancing the number of niches to be occupied by elements of the fauna. The presence of flowers, extrafloral nectaries and alternate prey associated with the intercrop and weed vegetation apparently allowed the weed-free and weedy polyculture plots to support higher natural enemies than weed-free monocultures.

Predation had not been measured but data collected on potential predators in the field showed that more predatory arthropods, except for spiders, were found in both weedy monocultures and polycultures than in weed-free monocultures.

Spiders as a group were persistently the most numerous predators which seemed to be slightly more abundant in soybean monocultures than in soybean/corn polycultures. Figure 27 showed that the peak of spider numbers occurred during the eleventh week after planting with the highest density of 8 spiders per 25 plants counted in soybean monocultures weed-free for only four weeks after planting. The lowest densities of 1.75 was counted in soybean/corn polycultures weed-free for only two weeks after planting.

Table 13 and Figure 28 showed that the number of coccinellid beetles are higher in soybean/corn polycultures as compared to soybean monocultures. The highest number of coccinellids of 3.5 coccinellid beetles per 25 plants which was counted on the eighth week in polycultures weed-free for only two weeks after planting coincided with the tasselling of corn and the flowering of soybean.

Syrphid fly densities seemed to be also more abundant in weedy soybean than in weed-free soybean (Figure 32). The highest number of syrphid flies of 1.25 flies per 25 plants was counted in soybean/corn polycultures weed-free throughout the season as compared to 1 syrphid fly per 25 plants counted in weed-free monocultures. These data were in agreement with published records that weedy sites that contain ample pollen as alternate food sources often harbor more stable populations of predaceous mites, syrphid larvae, and coccinellid beetles (Putnam 1964, van Endem 1968, Huffaker et al. 1970).

Figure 29 shows that Podisus sp. were the second most predominant predator species found in all the cropping systems. Population densities of Podisus sp. did not fluctuate heavily in all the cropping systems except in soybean monocultures weed-free for only four weeks after planting where the highest density of 4.5 Podisus sp. per 25 plants on the ninth week was counted. With greater numbers of Podisus sp. counted in monoculture plots except for polyculture plots weed-free for only two weeks after planting which was higher than counts in monocultures weed-free for only two weeks after planting, this predator seem to show preference of weedy monocultures than weedy polycultures. These relationships agree with a couple of studies that reported pest reduction due to an increase of natural enemies in weedy or intercropped fields. For instance, fall armyworm Spodoptera furgifera (J.E. Smith) incidence was consistently higher in weed-free corn plots than in corn plots containing natural weed complexes or selected weed associations (Altieri 1988). Barney et al. 1984 (quoted in Altieri 1988) reported that spring planted alfalfa plants infested with weeds had a less diverse substrate predator complex but a greater foliage predator complex than did weed-free plots. The carabid Harpalus pennsylvanicus (de Geer) and the foliage predators Orius insidius (Say) and Nabidae were more abundant in alfalfa fields where grass weeds were dominant. Highest density of 1.5 Geocoris sp. was counted on soybean monocultures weedy throughout the season. Note that no Geocoris sp. was observed in soybean monocultures weed-free throughout the season. The data presented in Figure 30 suggested that this predator has a high preference for weedy soybeans than weed-free soybeans. The biological behavior of Geocoris sp. as described above was similar to that for Stiretrus sp. No Stiretrus sp. were counted in both soybean monocultures and polycultures weed-free for only two weeks after planting (Figure 31).

Several other predatory and parasitic insects were also observed and collected from the weedy soybean monoculture and polyculture cropping systems but these were not directly counted.

Vegetation Diversity in Cropping Systems

Since plant community complexity increased from weed-free monocultures to weed-free polycultures and weedy monocultures to weedy polycultures, presumably soybean became less apparent to the stem fly because the growth of the weeds are more vigorous and therefore making the soybean less visible to the insect (Table 15). The trend of weed growth in polycultures is opposite to that for the monocultures. Weed growth in monocultures decreased with the time of weeding as manifested by the significant differences in the weights of the biomass. Monoculture plots in which weeds were suppressed during the initial two to four weeks of crop establishment showed lower weed growth than in monoculture plots which were allowed to remain weedy all season (Table 17). However, higher weed growth was observed in polyculture plots in which weeds were suppressed during the initial four weeks of crop establishment as compared to polycultures kept weed-free for only two weeks after planting or kept weedy throughout the season. Apparently, the shading provided by the overlapping corn and soybean canopies and the competition among weeds suppressed weed growth. Thus, polycultures seem to provide a wider range of resources for beneficial species to consume as well as more oviposition sites and shelter. Although the data on plant structural diversity were not recorded due to the complexity imposed by natural weed vegetation, it is assumed that the trend towards higher spatial heterogeneity in polycultures was maintained throughout the season.

From the vegetation diversity tests, it was apparent that the degree of diversity measured through the Shannon-Wiener function (H′), Simpson-Yule Index (D), species richness (rMa), and evennèss (J) in soybean/corn polycultures was higher than in soybean monocultures (Table 15). M. *sojae* populations were influenced directly by the concentrations or spatial dispersion of their food plants.

Table 4 suggested that vegetational diversity increases with the time of weeding with the highest vegetational diversity observed in the weedy cropping systems which had the least density of stem flies. It is therefore probable that these higher density of host and non-host material and the nature of associated plants in the diversified monocultures and polycultures might have caused greater difficulty to the stem fly in locating suitable soybean plants and in remaining in them once they found them. This agrees with the generally accepted resource concentration hypothesis that dense or pure patches of plants will favor those species that can find all their particular requisites within them. This frequently leads to a drop in insect species diversity where plant diversity is reduced and may lead to an increase in herbivore load on plants as stated by Root (1973).

The greatest emphasis on the value of diversity in pest control has been on the enhancement of natural enemies of pests. Data in Table 14 wherein weed-free polycultures and weedy monocultures and polycultures supported 7 species of natural enemies which was higher than in weed-free monocultures which supported only 6 species of natural enemies shows that predator colonization rates can be manipulated by vegetational diversity. The data in Table 15 on vegetational diversity that increased from monocultures and polycultures weed-free throughout the season to monocultures and polycultures weedy throughout the season also suggested that weeds positively affect the biology and dynamics of the beneficial insects. Altieri (1982) and van Endem (1965) indicated that diversified cropping systems offer many important requisites for natural enemies such as pollen or nectar, shelter or alternate hosts for neutral beneficial species as well as microhabitats which are not available in weed-free monocultures. These support the idea proposed by Risch (1981) that the probability that they will leave or become locally extinct is reduced. Altieri and Letourneau (1983) reported similar findings on Orius tristicolor and its preferred prey. Orius sp. density was significantly higher on squash early in the season in polycultures. Brussel sprouts Brassica oleraceae gemmifera var Jade Cross grown in polycultures with fava beans or wild mustard supported more species of natural enemies (six species of predators and eight species of parasites) than monocultures (three species of predators and three species of parasites).

The increase in vegetational diversity as shown in Table 14 may have added complexity to the interplanted crop eventually imposing physical obstacles to colonization of soybean by M. sojae as shown in Table 2 and 3. The weeds may have also acted as a camouflage and lessen the contrast between plant and soil so decreasing colonization as was observed for aphids (Smith 1969 and 1976, Cromartie 1975) and corn borer (Litsinger and Moody 1976). Dempster (1967) similarly recorded decreased oviposition by the small cabbage white butterfly Pieris rapae on brassicas growing among weeds (the white flowers of one weed species seemingly acting as an added visual deterrent).

Effects of Cropping Systems on Crop and Weed Yields

The positive effects of soybean/corn polycultures and allowing weed growth at certain periods of the crop growth on yields of soybean can be seen in Table 18. Highest yields of 120 g/25 soybean plants obtained from soybean/corn polycultures weed-free throughout the season was not statistically significantly different from 72.58, 94.40, and 101 g/25 plants of yields obtained from soybean monocultures weedy throughout the season, weed-free throughout the season, and weed-free for only four weeks after planting, respectively. Lowest yield of 36.49 g/25 plants which was obtained from soybean/corn polycultures weedy throughout the season was not statistically significantly different from 72.58, 63.01, 47.75, 64.96 g/25 plants which were obtained from soybean monocultures weedy throughout the season, weed-free for only two weeks after planting, and soybean/corn polycultures weed-free for only two and four weeks after planting, respectively.

Data in Table 18 suggested that there were statistically significant differences between corn yields in all the soybean/corn polyculture cropping systems. Corn yields were seemimgly directly related to the amount of competition of corn with other vegetations in each of the cropping systems. Highest yields of 5,868 g/25 corn plants were obtained from polycultures weed-free for only four weeks after planting whereas lowest yields of 570 g/25 corn plants were obtained from soybean/corn polycultures weedy throughout the season. Obviously, these differences in corn yields can be attributed to the differences in the amount of competition of corn with the other vegetations therein thereby resulting to the highest yield in cropping systems where corn only competed with soybean in polycultures weed-free throughout the season whereas lowest yields were obtained in cropping systems where corn presumably had the most competition in polycultures weedy throughout the season.

Competition between weeds and soybean were not measured. Therefore, there is no clear indication of the extent of competition between soybean and weeds in the various cropping systems. Data in Table 18 showed that weed and soybean biomass were statistically significantly different between treatments indicating that the longer the plots are weed-free, the lesser is the weed growth and therefore weed biomass. Monocultures kept weed-free for only two weeks after planting with higher weed growth as shown by its high biomass had statistically significantly higher soybean biomass and yields comparable to monocultures weed-free for only four weeks after planting. Monocultures weedy throughout the season had the highest weed biomass of 597.52 g/m^2 and the lowest soybean biomass of 204.11 g/m^2 but yields were comparable with monocultures weed-free for only two and four weeks after planting and weed-free throughout the season. Therefore, it seems probable that reduction in soybean yields in non weedy monoculture cropping systems is attributed to higher stem fly numbers. Since less stem flies were encountered in weedy monocultures and polycultures, reduction in yield can be more attributed to weed competition. Since the yields obtained in monocultures and polycultures weed-free for only two weeks after planting where less weeding was done were not statistically significantly different with other cropping systems, it is therefore recommended and preferrable than the other monoculture cropping systems.

Soybean yields in polycultures weed-free for only two and four weeks after planting were comparatively lower than yields in monocultures weed-free for only two and four weeks after planting but these were not statistically significantly different. It can therefore be argued that since no statistically significant differences occur between soybean yields from monocultures and polycultures weed-free for only two and four weeks after planting, in terms of labor requirements it is more economical and labor saving to weed soybean for only two weeks after planting. With extra corn yields obtained from polycultures, it is therefore more advantageous to intercrop soybean with corn rather than to grow it as a monocrop.