5. DISCUSSION AND CONCLUSIONS

This study was conducted to assess the effect of mungbean monoculture and mungbean mixed cultures on the diversity of insect species and the response of insect predators, parasitoids and herbivores under conditions similar to those practiced by farmers in the Chiang Mai valley. Some limitations which were encountered during the conduct of this study were mungbean and other associated crops replanting due to germination problems caused by heavy rain in July 1992 and the possible effects of the routine of pesticidal applications to the surrounding crops and other vegetation had on the dynamics of the insect populations in or nearby the experimental area.

5.1 Estimation of Herbivorous Insect Species Diversity

The complex structure of associated crops which grown in mixed cultures had a great effect on the fauna of the mungbean cropping system as shown in Table 1. The result of assessment of species diversity showed that the lowest value of H′ was 1.78 found in the mungbean/sorghum system ($P<0.01$). Whereas the highest value of H′ was 2.12 found in the mungbean/sesame system. However, there were no significant differences among the values of H′ in the mungbean/maize and the mungbean/upland rice systems in comparison to the mungbean monoculture. As a component of species diversity, the equitability (J) was also estimated for all mungbean cropping systems. The result of the study reveals that there were no significant differences between the values of equitability (J) in all mungbean cropping systems. The species richness (r_{MA}) in the mungbean mixed culture was significantly higher than that in the mungbean monoculture ($P<0.01$). The values of r_{MA} in the mungbean/upland rice and the mungbean/sesame system were higher than that in the mungbean monoculture. Except the values of r_{MA} of herbivorous insect in the mungbean/sorghum and the mungbean/maize systems were not significantly different with the mungbean monoculture. The finding of this study indicated that the value of H′ and r_{MA} in the mungbean/upland rice system was high in comparison with the mungbean monoculture system. This finding can be explained that the complex structure of associated upland rice crop provided food sources and habitats for herbivorous species, but also offered the important requisites for entomophagous species. Mungbean/upland rice system developed higher population of natural enemies which had a strong controlling impact on the build up of a potential pest. The results coincided with the increase of mean densities of natural enemies in mungbean/upland rice and mungbean/maize systems as shown in Table 7. The finding of this study also relates to the hypothesis of the resource concentration (Root 1973) and natural enemy hypothesis (Altieri 1962) as well. It means that dense standing crops will favor those species can find their own important requisites within them and also offer many important food sources, such as pollen, nectar as well as microhabitats for natural enemies.

The mean density of individual herbivorous insect species counted per 25 sweeps on mungbean in various mungbean cropping systems was combined into a total number in order to observe the trend of population growth throughout the season. There were significant differences between mean densities of herbivorous insects in mungbean cropping systems (P<0.01) (Table 2). The highest mean density was 40.14±9.97 found in the mungbean monoculture, whereas the lowest was 17.32±4.91 found in the mungbean/sorghum system. The population of herbivorous insects continuously increased with time and reached up the highest peak on the seventh week after planting with the population densities of 74.50 and declined to 9.50 on the tenth week in mungbean monoculture. The incidence of herbivorous insects on the seventh to the eighth week after planting coincided with the flowering and filling pod stages of mungbean. Apparently, mungbean crops provided hosts and food sources for many herbivorous insect species. This supports to the finding was reported by Root (1973) that, herbivores are more likely colonize and remain longer on crop host which grown in monoculture system because of uniform physical conditions. This result is also not in conflict with generally accepted resource concentration hypothesis stated that dense or pure stand of plant will favor those species that can find all their particular requisites within them. The population density of herbivorous insects in the mungbean mixed cultures was significantly lower than that in the mungbean monoculture (P<0.01). This can be explained that, the differences in structure of the crop canopy had possible affected on the behavior of several group of herbivores with less abundance in the mungbean mixed culture systems. The abundance population density of entomophagous species in the mungbean mixed cultures (Table 7) might have prevented the build up of population density of herbivorous insects in various mungbean mixed cultures as shown in Table 2. The finding of the study agrees with the conclusion given by Pimentel (1961), van Emden and William (1974), diversified crop provided a richer fauna than sole crops. There are more food sources for both herbivores and arthropods but also higher population of natural enemies. The findings of this study suggest that the characteristics of associated crops such as the tall plant and complex structure of crop canopy were mechanical barriers that interfered herbivorous insect dispersal behavior and decreased colonization efficiency which in turn resulted in lower population densities of herbivorous insects on the mungbean crop. Similarly, Way (1975), Tahvanainen and Root (1972) concluded that the mechanical barriers interfere with pest dispersal behavior and decrease colonization.

The population density of bean fly, <u>Ophiomyia phaseoli</u> Tyron in mungbean monoculture was significantly higher than in mungbean mixed cultures ($P<0.01$) (Table 3). The highest mean density of bean flies was 10.46±1.77 per 25 sweeps found in mungbean monoculture. The population density of bean flies increased as the season progress. Bean flies rapidly increased its population densities from the fourth week to the sixth week which coincided with the vegetative and reproductive stages of mungbean. Mungbean plants infested with high density of bean flies might have caused the reduction of mungbean yield, especially in the mungbean monoculture. Root (1973) indicated that herbivorous insects are more likely to colonize and remain on crop hosts that are concentrated in the simple environment. The finding of this study supports to the collusion given by Cromartie (1991) that, insect attacking is often more severe on plant grown in monoculture than in mixture. The lowest densities of 2.25±0.69, 5.03±2.01 and 2.78±0.56 bean flies per 25 sweeps were found in the mungbean/upland rice, mungbean/maize and mungbean/sesame systems. The results of this study suggests that mungbean mixed with upland rice, maize and sesame resulted in low bean fly densities. This can be explained that the complex in structure of companion crop canopies possible affected on the behavior of bean flies on mungbean. This also coincides with the finding was reported by Altieri and Liebman (1986) that the differences in structure of crop canopy in tall maize/soybean and short maize/soybean plots appeared to effect 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 population density of green stink bug, Nezara viridula Linneaus in the mungbean monoculture was significantly higher than in the mungbean mixed culture systems (P<0.05) (Table 4). This result agrees with the conclusion stated by Cromarties (1991) that, insect attacking is often more severe on plant growing in monoculture than in crop mixture or in diverse natural vegetation. The highest density was

5.39±2.28 per 25 sweeps found in mungbean monoculture. The mean density of stink bugs was found very low in the mungbean/sorghum, mungbean/upland rice and the mungbean/sesame systems. The seasonal abundance of stink bug reached its highest peak on the seventh to the eighth week after planting which coincided with the flowering and pod formation stages of mungbean. The incidence of green stink bug in the mungbean monoculture system during this period might have adversely affected on mungbean grain yield reduction. It is obvious to say that mungbean grown in uniform physical condition as monoculture system which provided concentrated food sources and encouraged herbivorous insect invasions. This period was also an attractive period for beneficial insects those remained longer in mungbean due to many requisites and ecological niches provided by companion crops. The finding of this study reveals that mungbean mixed with various crops (upland rice, sorghum and sesame) resulted in low stink bug densities. The result of this study is similar to the finding was reported by Altieri (1982) that, the population densities of Phylotreta cruciferae Goeze and Brevicoryne brassicae (Linneaus) 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 pest thus making the crops less apparent. This explanation is similar to the idea of Donal et. al (1986) stated that, planting of different varieties of crop species in the same field as the main crop is known as interplanting. Arthropod pest damage to the main crop can be reduced if the interplanted habitat interferes with pest colonization of the main crop and provides a reservoir for natural enemies. The results of our experiment suggest that mixed mungbean with various crops, such as upland rice, maize, sesame and sorghum that have differences in structure of the crop canopy exhibited lower green stink bug densities as compared to mungbean monoculture.

Throughout the mungbean growing season, the mean density of pod sucking bug, Riptortus sp. in mungbean monoculture was not significantly higher than in the mungbean mixed cultures (P>0.05) (Table 5). The highest peak of seasonal abundance of pod sucking bugs was reached on the seventh week after planting. The highest density was 2.00±0.78 bugs per 25 sweeps obtained from the mungbean monoculture. This results support to the findings reported by Root (1973) that, insect pests are more likely to colonized and remain longer on crop host which are concentrated in the simple environment. The increase of population densities of pod sucking bugs on the seventh week to the eighth week after planting which coincided with the flowering and pod filling stages of mungbean. This can be explained that mungbean plants provided concentrated resources which attracted its host invasion. Therefore, the incidence of Riptortus sp. in the mungbean monoculture might adversely affected on the development of mungbean pods.

5.2 Estimation of Natural Enemy Species Diversity

The applying of mixture of various crops in to mungbean cropping systems with complex structure had possible affected on the dynamic of natural enemy species. It is interesting to note that the values of H′index of diversity in the mungbean mixed cultures was higher than that in the mungbean monoculture as shown in Table 6. Apparently, in the mungbean/upland rice system with an H′ of 2.81 was 0.27 higher than in the mungbean monoculture with an H′ of 2.54. The value of H′ was found in the mungbean/sorghum and the mungbean/maize systems with an H′ of 2.75 and 2.55 respectively was 0.21 and 0.01 higher than in the mungbean monoculture with a H′ of 2.54. Except in the mungbean/sesame system the value H′ was slightly lower than that in the mungbean monoculture. However, there were no significant differences between the values of H′ as determined by F-Test. The values of evenness index (J) of natural enemy in the mungbean mixed cultures were also not significant different. Noticeably, in the mungbean/upland rice system had showed a tendency of increase of value of evenness (J) of natural enemy. The values of species richness (r_{MA}) of natural enemy in mixed cultures were significantly higher than that in the monoculture ($P<0.01$), especially in the mungbean/upland rice system exhibited the highest value of species richness r_{MA} was 22.61. Whereas in the mungbean monoculture the value of r_{MA} was 17.37. In the mungbean/sorghum and the mungbean/maize systems the value of r_{MA} was also higher than in the mungbean monoculture. It is obvious to say that the increase of species richness rHA of natural enemy in various mungbean mixed cultures was created by complex structure and spacial heterogeneity of companion crops, such as maize, upland rice and sorghum.

In other words, the finding of this study suggests that the increase of complex structure of mungbean mixed cultures such asmungbean/maize, mungbean/upland rice and mungbean/sorghum systems might have effects on the biology and dynamics of the entomophagous species. The diversified cropping systems such as mungbean/upland rice, mungbean/maize and mungbean/sorghum systems offered many important requisites for natural enemies, such as pollen or nectar, shelter or alternate host for natural enemies as well as microhabitats which are not available in mungbean monoculture. The finding of this study also coincides with the conclusion given by Root (1973) that, diversified systems supply better conditions for predators and parasites, reducing the likelihood that they will leave or become locally extinct.

The number of natural enemy caught per 25 sweeps was summarized in Table 7, and the results exhibit that there were statistically significant differences between the treatment means ($P<0.05$). The highest mean density of natural enemies was 10.89±2.83 found in the mungbean/upland rice system. Whereas the lowest mean density was 4.07±1.20 found in the mungbean monoculture. The highest peak of seasonal abundance of natural enemy in all mungbean cropping systems was reached on the seventh week, and still remained with a high population density on the eighth week and gradually declined in the end of mungbean growing season, especially in the mungbean/upland rice, mungbean/maize and the mungbean/sesame systems. Apparently, the highest peak of seasonal abundance of natural enemies occurred on the two periods (seventh and eighth week) was the reason of herbivorous insect densities sharply declined on the eighth week later (Table 2). In the mungbean monoculture the population density of natural enemy occurred earlier than in the mungbean/upland rice system with the mean density was 0.25 natural enemies on the fourth week and attained the highest peak on the sixth week with the population density was 9.00 natural enemies. Thereafter, the population density of natural enemies declined sharply on the tenth week. The findings of this study suggest that natural enemies were more abundant and remained longer in the mungbean/rice, mungbean/maize and the mungbean/sesame systems in comparison with mungbean monoculture (Table 7).

The seasonal abundance of predatory insects in all mungbean cropping systems was also observed. There were significant differences between the means of insect predators ($P<0.01$) (Table 9). The highest peak of seasonal abundance of predatory insects attained on the eighth week after planting which had related to the declination of population density of herbivores on the eighth week (Table 2). In contrast, predators had controlled the build up of the population density of herbivores. Apparently, in the mungbean/maize system the population density of predator reached up its peak on the ninth week. It means that in the mungbean/maize system had provided more food sources and ecological niches for predators. In other words, uniform physical condition or pure stand of mungbean was not attractive to predators. This contributed a good explanation to the low mean density of predators in mungbean monoculture system (Table 9).

The population density of parasitoids was also observed throughout the mungbean growing season. Mean densities of parasitoids in mixed cultures were significantly higher than that in the mungbean monoculture ($P<0.01$) (Table 15), especially the highest mean density of parasitoids was 6.36 ± 1.29 observed in the mungbean/upland rice system. Whereas the least mean density of parasitoids was 2.00 ± 0.33 observed in the mungbean monoculture system. There was a high fluctuation of population density of parasitoids as shown in Table 15. The trends of population of parasitoids increased in the end of mungbean growing season. This can be seen in various mungbean cropping systems. Apparently, in the mungbean/maize and the mungbean/upland rice systems the population of parasitoids reached its highest peak on the tenth week. The continuous increasing of parasitoid populations on the tenth week in the mungbean/maize and the mungbean/upland rice systems revealed that the mungbean mixed cultures offered more important requisites for parasitoids. The fluctuation of parasitoid populations in the mungbean/maize and the mungbean/upland rice systems was accounted for the population dynamics of their prey.

The fluctuation of population density of natural enemy in various mungbean cropping systems related to the fluctuation of their prey population throughout the mungbean growing season. The change in trend of population growth of herbivorous insect and its natural enemies can be clearly seen in Table 2, 7, 9 and 15. The abundance of mean densities of natural enemies, such as predators and parasitoids in the mungbean/upland rice and the mungbean/maize systems were the result of diverse systems. Similarly, Pimentel (1961), Price and Waldbauer (1975) also concluded that, mixed systems are found to have a richer fauna than sole crops because more herbivorous insect species can find their own ecological niches which in turn results in higher natural enemy population. This study suggests that diversified crops, such as mungbean/upland rice and mungbean/maize systems resulted in more food sources for higher population density of natural enemies which have a strong preventing the build up of a potential insect pest.

The response of predators and parasitoids to various mungbean cropping systems was summarized in Table 8 and 14. Table 8 showed that there were statistically significant differences between the total number of predators in the mixed cultures and the mungbean monoculture (P<0.05). Total number of predators in the mungbean/maize and the mungbean/upland rice systems was greater than that in the mungbean monoculture. This can also be explained by " Natural Enemy Hypothesis " (Root 1973). Likewise, total number of parasitoids in the mungbean/upland rice system was 6.45 also significantly higher than that in the mungbean monoculture (P<0.05) (Table 14). It is obvious to say that the diversified systems by mixed mungbean with upland rice and maize, provided important ecological niches, food sources for predators and parasitoids which resulted in higher population density of natural enemies in mungbean mixed cultures. There is no difference with the finding of Pimentel (1961), van Emden and Williams (1974) indicated that there is a potential beneficial effect of diversification resulting from increasing of natural enemies. The effect of designed cropping system on the response of some important beneficial insects was also observed in various mungbean cropping systems (Table 10, 11, 12 and 13).

The mungbean cropping systems had a positive effect on the abundance of coccinellid beetles, Menochelus sexmaculatus Fabricius and Micraspis discolor Fabricius. These coccinellid beetles were the most predominant predator species found in all mungbean cropping systems. Data in Table 10 showed that the number of M. sexmaculatus in the mungbean/maize system was higher than that in the mungbean monoculture. The highest number of M. sexmaculatus was 2.21±0.47 coccinellid beetles per 25 sweeps counted on the seventh week after planting coincided with the pod forming stage of mungbean (P<0.05). Data in Table 11 also showed that the highest peak of seasonal abundance of M. discolor was attained on the ninth week after planting coincided with the pod ripening stage of mungbean. The number of M. discolor in the mungbean/maize system was significantly higher than in the mungbean monoculture and others. The highest number of coccinellid beetles was 2.25±0.47 found in the mungbean/maize system (P<0.01). The result of the study was not in conflict with the finding reported by Cayme (1990) that coccinellid beetles were higher in soybean/corn polycultures than soybean monocultures. This study suggests that the mungbean/maize system had apossitive effect on the biology and dynamics of population density of coccinellid beetles. In other words, the diversified cropping systems increased spatial heterogeneity, complexity, and the amount of food sources. Thus, enhancing the number of niches to be occupied by the element of the fauna. The present of flowers, extrafloral nectars and alternate prey associated with the mixed crop to support higher coccinellid beetles.

Another entomophagous species, spider was also observed in various mungbean cropping systems. Spiders, *Oxyopes* sp. and *Phidipus* sp. were a second important group of numerous predators which seemed to be slightly more abundant in the mungbean mixed culture than in the mungbean monoculture. There was a heavy fluctuation of population density of spiders as the season progress (Table 12 and 13). Table 13 showed that the peak of spider *Phidipus* sp. was reached on the ninth week after planting. The highest mean density was 1.25±0.33 spiders per 25 sweeps found in the mungbean/maize system. The lowest mean density was 0.17±0.09 spiders per 25 sweeps found in the mungbean monoculture. The mean density of spider *Oxyopes* sp. was also recorded from mungbean/maize system that showed slightly higher than others.

However,there were no significant differences among the treatments. The finding of the study suggests that, associated crops created the biological niche which provided food sources for spiders. According to the result of observation indicated that the abundance of predators has a closed relationship with their prey in various mungbean cropping systems. However, the level of this relationship between spider and their specific preys needs for further study. Mixed mungbean cropping systems, such as mungbean/maize and mungbean/upland rice systems in which offered the many important requisites and microhabitat for spiders. Therefore, spider, Phidipus sp. still increased its population density till the end of mungbean growing season. The finding of this research was alsosimilar to the results reported by Cayme (1990), the population densities of spiders in soybean polycultures were higher than in soybean monocultures. And in the Philippines, Litsinger and Moody (1976) also reported that lycozid sp. preyed more heavily on maize borers intercropped with peanut than in monocultures. This result also supports to the findings reported by Perin (1977) and Ruhendi (1980) that tall crop provided more shade and humidity caused by dense crops which favor for spiders and predaceous arthropods.

5.3 Arthropod Species Diversity Assessment

The value of diversity measures was summarized in Table 16 revealed that there were no statistically significant differences between the values of H′ index species diversity in all mungbean cropping systems. However, there were significantly differences among the values of equitability (J) (P<0.01). Mungbean/sesame system exhibited the highest equitability J of 0.80 was 0.15 greater than in the mungbean monoculture with a J of 0.65 (P<0.01) (Table 16). It is interesting to note that the values of species richness (r_{MA}) in the mungbean mixed cultures were significantly higher than that in the monoculture (P<0.01). Particularly, the highest value of r_{MA} was 15.05 found in the mungbean/upland rice system. Apparently, the mungbean/upland rice mixed cultures showed a higher species richness than others. It is obvious to say that diversified cropping systemresulted in increasing of spatial heterogeneity and complexity. In contrast, the incorporation of various crops with mungbean in the cropping systems has increased the food sources. Therefore, enhancing the number of niches to be occupied by elements of fauna of mungbean cropping systems. The result of the study relates with the finding reported by Pimentel (1961), Price and Waldbauer (1975) that mixed systems are found to have a richer fauna than sole crops. Because not only there are more food sources for herbivorous insect species but also increase the population of natural enemies which control the insect pest from the outbreak. The differences in structure of associated crops affected the insect dispersal behavior and decrease colonization efficiency which resulted in lower density of herbivores in mungbean mixed cultures (Table 2). Tall crops also created the high relative humidity and more shade. The standing crops are the habitats of general entomophagous insects and spiders.