CHAPTER FIVE

Discussion and Conclusion

5.1 Laboratory Experiments

5.1.1 Stock Culture of *Ostrinia furnacalis* (Guenee)

Asian corn borer, *Ostrinia furnacalis* (Guenee), was reared in laboratory to provide sufficient numbers for the diverse purposes of other approaches studying this insect in either laboratory or field condition. Most experience in rearing Ost*rinia furnacalis Gu*eene has been obtained with this insect (Zhou et al. 1980). The rearing methods applied in this experiment showed that they were applicable. However, there was some variation in the food composition and methods used. That diet may affect the rate of development and survivorship of corn borer were studied by many workers. Matteson and Decker (1965) used string beans as a medium for rearing European corn borers to study the developmental rate. As the highest temperature (95°F) the beans had to be replaced every other day. That would disturb the larvae at higher temperature and would magnify an error in the actual lengths of stadia. Dittrick and Chiang (1981) studied the developmental rate of corn borer feeding on corn plants and meridic diet under greenhouse conditions. They found that the diet-reared borers developed faster than the corn-reared borers while exposed to the same number of degree days. Schroeder et al. (1986) also pointed out that optimal laboratory rearing was dependent on a quality artificial diet.

In this experiment, a artificial diet for Asian corn borer larval growth suggested by Zhou et al. (1980) and paid more attention on the hygiene and avoided larval aggression demonstrated that was preferred in the category of laboratory experiment. The results suggested the rearing diet as developed by Zhou et al. (1980) and their rearing methods were suitable to provide sufficient Asian corn borer for various purposes. This method was a primary work, however, it needs further work to reveal other aspects of the rearing methods used in this experiment which affect behavior, biology, and genetic characters of Asian corn borer rather than only in the oviposion aspect.

5.1.2 The Effect of Temperature on the Duration of Development of *Ostrinia furnacalis* (Guenee)

When reciprocals of the duration of each stage of corn borer being reared at constant temperature are plotted against temperature, a S-shaped curve of development, including the approximately linear region of development curve is valid (Matteson 1965). Since gross error in predicted development rates occur at the temperature extremes (Stinner et al. 1974), so the methods for calculating degree days allow for upper and lower thresholds (Allen 1976, Higley et al. 1986). Once a developmental threshold is determined, the experimental data can be used further to establish thermal constants for important events in the Asian corn borer life cycle (Zhang et al. 1979, Zhu and Zhang 1988).

As early as 1927, Caffrey and Worthley have stated that the velocity line of European corn borer was straight only within the ranges of temperature of 67-87.5°F for eggs, 61-81°F for larvae, and 62.5-87°F for pupae; simultaneously, they calculated the straight line threshold for the eggs, larvae, and pupae of the corn borer were 58.7°F, 49.7°

F, and 55.4°F, respectively. Matteson et al (1965) reported the similar result for the velocity line of European corn borer range of development was within the temperatures 65-80°F for egg, 60-90°F for larva, and 60-85°F for pupa. Beck (1983) estimated the developmental threshold temperature characteristic of the first four larval instars of European corn borer under both thermoperiod and constant temperature. He found that the developmental threshold for first stadium to fifth stadium under constant temperature was 10.9°C, and was 11.1°C under thermoperiod condition, respectively. Zhu and Zhang (1988) estimated that the developmental threshold for the eggs, larvae, and pupae of Asian corn borer were 13.5°C, 6.4°C, and 11.8°C, respectively. The degree-day accumulations were 44.7 for eggs, 452.1 for larvae, and 115.5 for pupae. Zhang et al (1979) stated that the developmental thresholds of Asian corn borer were 13°C for egg, 11.2°C for larva, and 12.6°C for pupa. The degree-day accumulations for the egg, larva, and pupa of Asian corn borer were 50, 365, and 91, respectively.

All of the studies as mentioned above were the use of linear equations to describe developmental rate, then achieved the lower developmental threshold temperatures. The method has been criticized by a number of researchers (Stinner et al. 1974, Sharpe et al. 1977, Li and Wang 1986). They argued that at temperature extremes, developmental velocities did not follow a linear path, but tended to approach a maximum developmental temperature and then decline until mortality occurred. At lower temperatures, insect development slowed, but continued beyond the base temperature predicted by a linear function. If insects would be exposed to extreme temperatures during development prediction periods, functions other than linear equations must be utilized. To capture the nonlinearity of Asian corn borer development for determining the higher limit temperature threshold, a sigmoid function described by Stinner et al. (1974) was employed in this study to attempt determine the parameters of degree-day model more accuracy.

The results of laboratory experiment in this investigation revealed the detrimental effects of extreme temperatures on immature development of Asian corn borer, but were otherwise consistent across temperatures, indicating that optimal development occurred between 16°C and 30°C. However, the velocity line of the combined immature stages varied from the normal at its upper and lower limits, as with the velocity lines of the individual immature.

There was a decrease in developmental time with increasing temperature for most life stages up to 30°C, above which developmental time increased. The exception was the egg stage, whose developmental time decreased only up to 26°C, after which they increased.

Estimates of minimum development and upper limited thresholds were similar for all developmental stages except the pupae which had a about 1°C higher than those of other stadia at lower developmental threshold; and eggs which had a about 3°C lower than other stadia at upper limit threshold. Averaged over all stadia, a pooled lower developmental threshold was estimated to be 10.35°C. Reports of lower developmental thresholds for other temperate-zone Asian corn borer varied from each other. Yie (1978) determined 9°C to be the minimum developmental threshold for Asian corn borer in northern China. Liu (1979) estimated it as 12.5°C in central China. It had been proved that a 10°C base temperature consistently gave the best fit to south-western China from the this field experiments. General speaking, there have not been the reports referring the upper developmental thresholds of Asian corn borer in China.

From this experiment, it might be realized that within limits, for example, 12 to 26° C in egg stage, 14 to 30°C in larval stage and pupal stage, higher temperatures produced greater growth rates because reaction proceed more rapidly at higher temperatures. As temperature increase, diffusion rates for substrates or enzymes or both also increase, resulting in greater formation of enzyme/substrate complexes. Additionally, higher temperatures provide more thermal energy for meeting energy requirements of the reaction (Sharpe et al. 1977).

Although some approaches for calculating lower developmental threshold are available (Kirk and Aliniazee 1981, Zhang and Li 1986), they also produced estimated values. So x-intercept method which employed in this approach was acceptable. Whichever method is used to determine the lower developmental thresholds, thus, in calculating degree-days, invariably introduces some inaccuracy (Higley et al 1986).

Estimating a upper limited threshold is a challenging because the variability in developmental rates is usually greater at higher temperatures and because mortality is high. Presently available techniques for calculating upper developmental threshold are not precise (Higley et al. 1986). Furthermore, developmental maxima were not determined for applying the studies on Asian corn borer (Zhang and Zhu 1988). Determine upper limited threshold temperatures in this study attempted to reduce the error induced by lacking upper developmental threshold for calculating degree-days in the investigation of Asian corn borer. This approach in this experiment was in a sense more applicable in the conditions of Yunnan.

5.1.3 Life Table Study of *Ostrinia furnacalis* (Guenee)

The investigation of the survivorship of the Asian corn borer at constant temperatures is meager. Therefore, information pertinent to this field must suffice. Morris et al. (1970) studied the impacts of various combinations of temperature and humidity to the survival and development of *Hyphantria cunea*. They constructed the life tables of *H. cunea* and provided a pre-model of temperature and humidity to influence the rate of survival. Wu et al. (1978) built the life tables of cotton bollworm at different constant temperatures. The experimental results showed the influence of temperature on survival percentages of this cotton insect differed during different developmental stages. Titayavan (1986) examined the mortality of *Lamprosema spp*. occurred in their various developmental stages under different constant temperatures. The mortality rate was fairly low in both the egg and pupal stages of *L. indicata* when compared to the larval mortality. Less 50 per cent of *Lamprosema spp.* became adult insects. Rock and Shaffer (1983) reported the survival rate of codling moth was greatest at 27°C but did not significantly among the temperatures 16, 21, 27, and 32°C was 36.7, 39.2, 46.7, and 43.7, respectively.

From this experiment, it is clearly showed that temperature was a principle factor to influence Asian corn borer from another angle and extreme temperatures were capable of killing of them. It also could be concluded that the mortality was low when Asian corn borer reached to larval stages. The mortalities of first instar and second instar were lower than those of third instar to fifth instars. This phenomenon caused the difficulties of controlling work under natural conditions because the borers went bored into stalk of plants after third instar (Zhang 1981). Although probably field experiment can give a more realistic estimate of capability of temperature to act on Asian corn borer, but it is usually impossible to exclude all causes of mortality other than the one under investigation and it is often difficult and expensive to replicate field experiments adequately. Moreover, much of confusion and controversy surrounding the regulation of Asian corn borer population might be traced to the lack of adequate field data in Yunnan, the interpretation of temperature regulatory mechanism had been largely based on a priori assumptions using models derived from controlled laboratory experiments of disconnected field data. Such the simulations were essentially deductive in that they had not had the benefit of precise data from carefully planned population of Asian corn borer studies in which all of the relevant factors had been measured accurately.

5.2 Field Experiments

5.2.1 Response of *Ostrinia furnacalis* (Guenee) to the Light Trap

The use of capture, trapping and other sampling methods plays an essential part in all studies on the ecological and behavior of insects in the field. The interpretation of capture data obtained by a single technique, however, can be extremely difficult or speculative, and it has therefore been recognized that wherever possible the evaluation of a particular technique should be assisted by data obtained simultaneously by a comparison technique using quite different principles of capture or attraction (Muirhead-Thomson 1991). Studies on the phenology of adult moth of corn borer usually use either pheromones or blacklight as trap (Jarvis and Brindley 1965, Mcleod 1976, Zhang et al. 1979, Despins and Roberts 1984, Lu 1992). Flectcher-Howell et al. (1983) found that the light trap of European corn borer recorded some activity in certain period which was out replicated in the pheromone trap, and the peak pheromone trap was significantly different with light trap. A study on Asian corn borer in northern China also indicated that pheromone-baited traps performed poorly in relation to blacklight traps and that catches in pheromone traps peaked after the light trap maxima (HNURG 1977). The reduced efficiency of the pheromone traps was attributed to competition for males by females (Muirchead-Thomson 1991).

Data from blacklight and pheromone traps clearly showed that, annually, the Asian corn borer had three flight periods in Yongde, Yunnan, but field data indicated that only two generations in corn. This is because that the third flight period occurred after the corn had matured; therefore, it was too late to allow successful development of a third generation on this host plant.

5.2.2 Response of *Ostrinia furnacalis* (Guenee) to the Synthetic Sex Pheromone

The quantity of moth catch somewhat differed between blacklight and pheromone traps, but peak flight periods occurred at about same time except the third generation peak which pheromone trap lagged one week than that of blacklight trap. Comparison with blacklight trap versus pheromone trap, both traps reflected the beginning of the first flight in mid-May, at which period the pheromone trap caught considerably more than the light trap. From third week of June until last week of July, the light trap recorded some activity which was not replicated in the pheromone trap. However, in the second flight, the peak pheromone trap capture was on identical with blacklight trap. But, the peak pheromone trap capture was on second week of September in the third flight, delayed one week than that of light trap. The reason possibly due to depression of pheromone attraction caused by competition with feral females (Zhang et al. 1979). Another reason perhaps the trap catch is influenced by the proportion of "calling females" (Zhang 1981). Ovipositing female may not be interested in mating, so that an imbalance between males and receptive females occurs, leading to a pheromone trap peak after oviposion rather than before it (Lu 1992)

5.2.3 Sampling for Immature Populations of *Ostrinia furnacalis* (Guenee)

Larvae unable to complete their feeding and attain maturity before the end of the growing season did not survive the winter or left the corn plants to feed on alternative host plants. Otherwise, larvae attained to the last larval instar began to diapause and spend the winter in the corn plants or in other cornfield debris. Appearance of the first generation borer eggs and larvae coincided with corn whorl, and the second generation borer eggs and larvae coincided with corn tasseling and silking. The feeding behavior of second generation neonates might explain the relation in egg-laying and corn tasseling. The moth does not feed, but selects host plants based on the needs of the larvae (Zhang 1981). By laying eggs on corn assure adequate food supplies for their progenies. In tasseling plants, the new larvae feed initially on pollen.

The distribution of counts egg masses for the plant sample unit could be described by a Poisson model; but medium and larger larvae of both generation, and first generation pupae just should be described to a less aggregation in the distributions mentioned as above. However, the Poisson model did not imply that true population randomness existed because this demanded that biological independence (Taylor 1984); the oviposition of an egg mass could not influence the oviposition of another egg mass on the same plant. Rather, a situation of pseudo-randomness probably occurred, which interactions could not be distinguished and the variance of sample observations was not significantly different from the mean. Nonetheless, the Poisson distribution was a good descriptive model for these sample observations. Wu and Din (1965) reached similar conclusions with first generation Asian corn borer egg deposition in Beijing, China.

When making decisions on the need for control of Asian corn borer, it is necessary to know the density, or index thereof, of eggs and early instars. This is because small larvae are the best life stage to control and eggs plus small larvae give the best measure of the threat of Asian corn borer damage. An estimate of egg mass density alone is not sufficient since such an estimate assesses the rate of oviposition over a narrow window (ca. 3-5 days). By including small larvae in the sample, the period of time in which oviposition activity is measured increased by up to 7 days. Although egg masses are distributed randomly, the small larvae that emerge are aggregated on single plants. As a result, a problem arises of how to design a sample plant that incorporates information from two populations that have different dispersion characteristics. One solution is to develop a measure common to both populations through which one population can be related to another.

5.2.4 Arthropod Population Density Assessment.

The dynamic of arthropod taxa and abundance in three different growth periods of corn revealed that plant architecture and arthropod species diversity were correlated (Lawton 1983). In this experiment, it was clearly showed that corn plants built up their architecture from nothing; leaves, stems, flowers, and ears were added as the corn matures. With this seasonal buildup in the complexity and variety of above ground parts came a buildup in the diversity of arthropod especially phytophagous insects. An obvious incidence was that architecturally simple stage (seedling) supported fewer species of arthropod than the following growth stages of corn. During seedling stage, only 8 species of arthropod versus 19 arthropod species in tasseling stage and 17 arthropod species in physiological stage. However, during seedling period, species richness were concentrated in the underground subcommunity, the most abundant habitat, underground insects and overwintering functional groups dominated. As the corn plants developed, both quantitative and qualitative changes in the habitat occurred. The number of arthropods found in a corn fields increased as the season progressed. Up to tasseling stage of corn, either species richness or abundance was the maximum in this investigation. As corn plants began to senesce (physiological mature), abundance and richness of arthropods decreased. The difference of arthropod species evenness indices in different developmental stages of corn suggested that the decreasing of evenness values in late stages of corn might be caused by addition of rare species and the co-dominant species became decline. Otherwise, that in seedling stage the evenness was higher was resulted from the less rare arthropod species and co-dominant species was high. However, most often, the evenness indices are more difficult to interpret (Ludwig and Reynolds 1988).

Part of the seasonal progression of herbivores on corn plants was dictated not by the absolute presence or absence of some critical resource but by marked seasonal changes in chemistry, toughness, and general palatability of foliage, stems, fruits etc. (Lawton 1978). Hence, leaves or fruits were not one resource for herbivores, but a series of temporally overlapping resources. They followed that many phytophagous insects were seasonal specialists. Then, corn plants with seasonal changes in foliage, stem, ear etc. characteristics should display a seasonal turnover in their faunas, and hence be attacked by more sorts of insects in toto than corn with more conservative seasonal strategies. Data on age-related changes in corn plants characteristics (among seedling, tasseling, and physiological mature) and their effects on fauna diversity probably reflected a relation between plant architecture and the diversity of arthropods in this experiment.

5.2.5 Degree-Day Accumulations under Field Conditions

Many researchers have pointed out that insecticide treatment against corn borer must be applied when young larvae are present before they bore into stalk. And this period can be determined by observing either moth flight or the occurrence and magnitude of egg mass deposition (Zhang et al 1979, Zhang 1981, Showers et al 1983). However, the most frequent mistakes occurred in the timeliness of egg mass counts since searching for egg masses could be time-consuming and was often observer-dependent (Apple 1952, Boivin et al 1986). The date on which 50% oviposition would be completed had been a key to insecticide application (Zhang et al. 1979). Actually this date was not able to be determined accurately until all oviposition had been completed (Jarvis and Brindley 1965).

Apple (1952) proposed using degree-days model with lower developmental threshold of 50°F for the appearance of various stages in the life cycle of European corn borer in Wisconsin. This model was used to be as a guide to indicate the proper time to make an evaluation of the corn borer infestation and time to make insecticide applications. To coincide with the egg hatching period, for first generation, he recommended that treatment be applied at 1,000 degree-days which was equivalent to the time of 50 per cent egg hatching. If ear damage was more than 25 per cent, a second insecticide application was suggested at 1,200 degree-days. The accumulations of degree-days started with the firs daily mean temperature above 50°F.

The relationship between degree-days and cumulative percentages of first- and second-generation European corn borer moth flight and oviposition was presented in Iowa (Jarvis and Brindley 1965). The equation could be used to predict the date on which any desired percentage of first- and second-generation moth flight or oviposition. Monitoring the accumulation of degree-days was proven useful in predicting European corn borer stage phenology in North Dakota (Frye 1971) and Ohio (Clement et al. 1981). Zhang et al (1979) monitored the accumulations of degree-days which have been proven useful to predict Asian corn borer stage phenology in northern China to certain extent. Despins et al (1984) measured temperature fluctuation and used blacklight as trap to have developed a predictive system in Virginia.

The accuracy with which a degree-day model predicted European corn borer event depended on the accuracy of the developmental threshold and the precise time that the degree-days accumulation begins (Showers et al. 1983). However, accumulation of degree-days were arbitrary started whenever base temperature occurred or chosen at certain date which was first captured by either light trap or pheromone trap. Because of population diversity and environmental factors, these degree-day predictions had not functioned well (Showers et al. 1983). And use such arbitrary starting times was likely to become a major source of error in any degree-day accumulation because predict insect development after a period of diapause or dormancy the initiation times may not be easily defined (Pruess 1983). In a complex community, the emergence time of insects were varied and hard to determine the actually happening time in the fields. If just tread the first capture as the beginning of degree days accumulation usually consulted in big bias. Furthermore, the first capture was usually effected by climatic factors so as to the first capture was not reliable. In this experiment 1 January was used to the beginning of degree-days accumulation. The result suggested that this way to calculate the degree-days for events of Asian corn borer was practicable.

Boivin et al. (1986) first proposed using pheromone traps and a degree-day model with lower and upper developmental thresholds of 10°C and 35°C to time insecticide sprays. Lee and Spence (1987) adopted vary sets of lower and upper temperature thresholds to study two Alberta populations of European corn borer. They found different threshold temperatures closely linked with developmental adaptation of corn borer populations. Degree-day method to predict phenological events of corn borer is not a universal mean in each area. The actual accumulations of degree-days necessary to reach a determined phenological stage could vary from one place to another (Jarvis and Brindley 1965, Mcleod 1976, Despins and Roberts 1984).

The results of this experiment revealed that the average heat unit accumulation between peak flight with both traps was more close to the 539.51 degree-days required to complete development from egg to adult previous determined in the laboratory. However, there were deviations between the first to last captures of each generation. The difference in degree-days between the first and later generations differed with the expected indicating that development of Asian corn borer during the first and last captures of each generation was varied by the affects of environmental factors and their biology, or both. During the first generation (May-June), there was less precipitation and alternative host plants, but later, the frequency of occurrence of unsuitable climate factors such as somewhat frequent precipitation and changeable temperature or between the first to last captures of each generation were similar to temperatures during summer moths. From May to September at Yongde is raining season, but the temperature is not so high to exceed the upper threshold of Asian corn borer during this season in common years. For this reason, more precipitation could be attributed to the variance in degree-days between the expected and the first and last captures of each generation. Furthermore, calculating degree-days of whole generation of Asian corn borer under field conditions using the first and last captures of each generation might be less accuracy compared to use the peak flight as a definite time to calculate degree-days accumulation for whole generation. Percentage cumulative emergence versus light and pheromone traps catch were plotted on a time-temperature scale (degree-days). In both traps, catch curves deviated each other. Those catch totals suggested that actual different in population density between light and pheromone captures. According to the results of this experiment, it should be noticed that light trap performed somehow well than did by pheromone. Light trap either using flight peak of each generation of Asian corn borer or using first and last captures to determine the phenology and the relation between cumulative percentage of moth flight and the degree days accumulation was close to the expected heat unit requirement of each live stage estimated in previous laboratory study. However, pheromone trap was less accurate in the sense of degree days accumulation. Because of the nature of the pheromone and its possible interaction and competition with the females population there was some question of the same trap catch interpretation could be applied throughout a whole season. Pheromone trap poorly mimics the natural males might be female of Asian corn borer density too high and the trap density too low (in this experiment was only 2 traps). And the relative attractiveness of the artificial pheromone was not effective and the souse was impended by other obstacles.

The reliability of the method of degree-days cumulating for predicting seasonal development of corn borer could be increased by including its other live stages (Showers et al. 1983). Accumulated degree-days for completion of each life stage were studied in this experiment. Using the dates on which peak numbers were observed in the field, the degree-days above 10.35°C (D_L = 10.35°C, D_U = 32.0°C) accumulated during development of each stage were calculated. These data were compared with the thermal requirement derived for each stage and tested by chi-square. Results showed that the observed degree-days accumulated between stages did not differ significantly from those expected. The egg and small larvae stages are the key periods to control corn borer (Zhang 1980), timing of them combined adult surveillance based on the degree-days accumulation could reach the predicting results more efficiently. In particular, the start of moth flights in the field may not be obvious because of the overlap of generations. It may be concluded that proper timing for samples of eggs, larvae and pupae of the Asian corn borer could be determined provided only that the pertinent daily temperature data are available and the first occurrence or peak of an earlier stage is known. Despite these works were most undue complexity in investigations and there were certain deviations in the degree-days, especially using first and last captures of each generation as a index of whole generation, however, discrepancy could be easily modified by statistic methods (Pruess 1983).