CHAPTER IV

Evaluate the role of natural enemies and cropping systems on the population management of *Helicoverpa armigera* (Hübner)
I. INTRODUCTION

The cotton bollworm, *H. armigera* (Hubner) is a major constraint to food, fibre, and horticultural crops production in India (Reed and Pawar, 1982). Its perception as a particularly serious pest derived from its polyphagy, high fecundity, and short generation time, high mortality, preference for the harvestable fruiting parts of its host plant, and propensity to develop resistance to chemical insecticides (Kranthi et al., 2003). Insecticide application represents the conventional control practice for *H. armigera* on several crops; however, increasing insecticide resistance has led to a greater risk of control failure (Armes et al., 1992). This situation warrants more sustainable methods of pest control. Increased biological control through conservation and augmentation of native natural enemies by manipulation of cropping environment represents one such control option. Majority of the mortality factors of *H. armigera* occurs during the egg and early larval instar stages in cotton (Titmarsh 1985; Teetes et al., 1992; Wilson, 1994). The severity of *H. armigera* attack varied not only between crops and regions, but also on a temporal scale. Low economic damage thresholds in high value crops like cotton, tomato, pulses, and tobacco require a high level of control that leads to reliance on heavy and frequent use of chemical insecticides. Most studies on natural enemies of the cotton bollworm have focused on parasitoids that attack the bollworm eggs and larvae, and often in cotton cropping systems (King, 1994). In fact, natural enemy data are largely restricted to records only, with a few studies providing quantitative information such as percent parasitism (Romeis et al., 1996). Naturally occurring populations of the egg parasite, *Trichogramma* spp. have been shown to cause high levels of parasitism on many crops (Hoffman et al., 1990; Steward et al., 1990). Species of *Trichogramma* are also often released as inundative (Stinner et al., 1977) and augmentative (Fye and Larson, 1969; Johnson, 1985), biological control programs against *Helicoverpa* spp. to maximize early mortality. However, the levels of egg parasitism by *Trichogramma* spp. is known to vary between host plans on which *H. armigera* infestation occurred (Manjunath et al., 1989). *Trichogramma chilonis*, which causes high levels of parasitism on *H. armigera* eggs in companion crops of sorghum and cotton. However, this did not prevent the cotton from indiscriminate applications of insecticides undermining the role of egg-parasitism by *T.*
In order to incorporate egg-parasitoids as a component in pest management programs, there is a need to have systematic studies on the need to have systematic studies on its role as a mortality factor of *H. armigera*, as the cotton farming community are on the look out for the impact of beneficial organisms, under field conditions, before making control decisions. Integrated control program on *H. armigera* seek to minimize pesticide inputs and maximize the impact of natural enemies, but a major constraint to their development particularly on cotton has been the need to deal with a diverse pests where control needs may conflict.

Parsons and Ullyett (1936) were the first to report mass production and inundative releases of *Trichogramma lutea* against *H. armigera*. Subsequently, several egg-parasitoids such as *T. chilonis* Ishii, *T. perskinsin* Girault, *T. semifumatum* Perkins, *T. pretiosum* Riley (Twine and Loyd, 1982; Johnson, 1985; King et al., 1985; Abdelrahman and Munir, 1989); *T. pintoi* (Voegele) in Tajikistan (Middle Asia) (Kovalenskov, 1992), *T. confusum* (Viggiani) in China (Zhou, 1988), *T. ostrinia* Pang and Chen (Gou, 1986), and *Trichogrammatoidea brasiliensis* (Ashmead) have been tested in cotton and maize agroecosystems, but were not established under field conditions (van Hamburg, 1980; Kfir, 1981, 1982). However, Bournier and Peyrelongue (1973) were not only able to control *H. armigera* by *T. brasiliensis* but delayed the infestation of *H. armigera* and reduced the number of applications. While Kuklinski and Borgemeister (2002) obtained 32% parasitism by *T. evanescens* Westwood in Madagascar Island. *T. chilonis* had a significant impact on the population of *H. armigera* in India (Pawar et al., 1986, 1989; Jadhav et al., 2000), and Island of Santiago (Cape Verde Islands) (van Harten et al., 1990). Several *Trichogramma* spp. have been mass produced and released on 20 crop species (Li-Ying, 1994; Smith, 1996; Hassan, 1998).

Planting of different cropping systems had a significant impact not only on the oviposition of adults and the larval movement of *H. armigera* but also on population dynamics of natural enemies. Neighboring crops serve as a source/sink of pest infestation for population buildup/mortality (Nyambo, 1988). The vegetative growth stage of cotton offers an opportunity for long-term pest-parasitoid interactions and was found to keep the
populations of *H. armigera* from reaching the economic threshold levels in southern Uganda (Coaker, 1969). Similarly, maize planted adjacent or intercropped with cotton in Tanzania (Pearson, 1958), and sorghum with pigeonpea in India significantly reduced the impact of *H. armigera* on the companion crops (Duffield, 1994a,b; Romeis, et al., 1999). Further evidence indicated that natural enemies to the neighboring cotton received the benefits from grain sorghum (Massey and Young, 1975; Krauter et al., 1998; Prasifka et al., 1999a,b; 2004; Mamogobo et al., 2003). Robinson et al. (1972) observed increased populations of the predators such as coccinellids, *Chrysoperla carnea*, nabids, and other spiders on cotton planted as a sole crop adjacent to sorghum. The grain sorghum has recently been effectively used as a trap crop for corn earworm, *Helicoverpa zea* (Boddie) on cotton (Tillman and Ruberson, 2001; Tillman and Mullinix, 2004).

II. MATERIALS AND METHODS

Experimental site

During the rainy season, an experimental site in farmer’s field measuring 0.50 ha was selected in Medak district, Andhra Pradesh. A medium duration of two non-Bt cotton hybrids [cv. MECH-12; 150-170 days] and a long-duration hybrid sorghum [cv. CSH-9; 120 days] were planted as intercrops in the ratio of 4:10 on June 24 and 25, 2004 (Fig. 4 1) Plant to plant and row spacing was 6 cm and 45 cm for sorghum, and 15 cm and 50 cm for cotton, respectively. Sorghum flowering and cotton squaring takes 70-80 days, and 100 days after planting, respectively.
Fig. 4.1. Field plot arrangement of sorghum and cotton intercrop in 4:10 rows for the incidence of *H. armigera* and egg parasitism by *Trichogramma chilonis* (Diagram is not to scale).
Sampling of *H. armigera* eggs on sorghum and cotton

Sampling of eggs made from the natural population of *H. armigera*. At weekly intervals, randomly selected ten sorghum panicles and leaves of twenty cotton plants were sampled during August-September and September-November, respectively. Samples were taken at five intervals during flowering to soft dough stage in sorghum, and nine samples flowering to squaring in cotton. Samples were collected in muslin cloth bags brought to the laboratory, and placed in a square aluminium trays for recording observations under a magnifying lens by removing the eggs with a camel hair brush individually into transparent glass vials (5 cm long and 1 cm wide), and maintained at 25±1º C and 60% RH. These vials were constantly monitored for the emergence of either larvae of *H. armigera* or the parasitoid of *T. chilonis* on alternate days. Egg parasitism was determined by dividing the number of eggs parasitized by *T. chilonis* from the total number of eggs sampled, excluding those which failed to hatch due to infertility, damage, or desiccation. The present values were arcsine transformed before subjected to analysis of variance and the means were separated by LSD (P>0.05).

III. RESULTS

There is a gradual increase in egg density of *H. armigera* on sorghum panicles during August-September, but declined at different intervals from 55 to 29 sample⁻¹ on sorghum, and 56 to 15 sample⁻¹ on cotton. Parasitism by *T. chilonis* on sorghum initially started with 18.2% in August and reached a peak of 51.8% in the second week of September, with a subsequent decline to 10.3% (Fig. 4.2). On cotton, the rate of oviposition was commenced during second week of September (17.9%), which reached a smaller peak by September last end (34.2%), and bigger peak by October second week (60.9%) followed a decline to 13.3% by November beginning (Fig.4.3). These periods coincided with flowering, boll-formation, and crop senescence stages of cotton indicating a more prolonged period of oviposition compared to sorghum. The peak period of oviposition
was corresponded with an average availability of 25 squares and/or young bolls cotton plant\(^1\). Egg clutch size (586) revealed emergence and gregarious-parasitism with 1, 2, 3, and 4 numbers and 15.9, 39.0, 25.6, and 19.5% on sorghum (Fig. 4.4), and egg-clutch size (1011) of 1, 2, 3, 4, and 5 parasitoids with 19.0, 45.7, 27.4, 5.6, and 2.1% on cotton, respectively (Fig. 4.5). Farmers planting of cotton adjacent to sorghum in Ranga Reddy district is shown in (Fig. 4.6).

These results demonstrate the compatibility of new high yielding cotton cultivars in different crop combinations. By creating a more continuous cropping environment natural enemies can be encouraged to move between different crops. For such a cropping system to provide a viable option of *H. armigera* management, it is necessary to demonstrate that the increased levels of natural enemy activity result in a significant reduction in pest populations, which in turn would result either in reduced damage or number of pesticide applications to the cotton bollworm.
IV. DISCUSSION

Vegetational diversity had a significant impact and offers a chance for long-term stability of host parasitoid interaction in southern Uganda (Coaker, 1969; Dempeter and Coaker, 1974). However, in southern Tanzania, the dry season induces diapause in *Heliothis*, which limits successful biological control (Reed, 1985). This habitat is mostly predominant for annual crops, where standing vegetation is regularly renewed and chopped based on its maturity cycle. In Andhra Pradesh, agricultural crops are predominantly grown in smallholder cropping environments, comprising a mosaic of crops such as cotton, sorghum, maize, sunflower, mungbean, soyabean, fruits, vegetables, and ornamentals. *H. armigera* has developed resistance to a diverse range of insecticides resulting in failure of pest suppression in diverse agroecosystems, particularly on cotton and legumes (McCaffery et al., 1989; Armes et al., 1996; Kranthi et al., 2003), and thus the declining impact of parasitoids (Balla, 1982). This implies the need to develop control strategies, which seek to maximize the contribution of natural enemies to reduce *H. armigera* populations (Greathead and Waage, 1983). In contrast, the planting of maize with cotton increase the abundance of *H. armigera* because the pest multiplies on maize and migrates to cotton without a check by natural enemies (Pearson, 1958). Moreover, the growth stage of each crop present at the invasion time of *H. armigera* usually
determines whether or not diversion from the main crop will occur. In Peru, this system with irrigation, favored the control of *H. armigera* including other pests by creating a stable and self contained environment long enough for natural enemies to be effective (Wille, 1958; Southwood and Way, 1970). In Rhodesia and Sudan, the intercropped maize has frequently failed to protect cotton (Bebbington and Allan, 1933). In the USA, early planting became a major source of *H. zea* attacking cotton (Henry and Adkisson, 1965), and the cropping patterns of maize and tomatoes established a favorable sequence of *H. armigera* leading to severe infestations on cotton (Way 1975).

Promising biocontrol agents against *H. armigera* are egg parasitoids belonging to the genus *Trichogramma* can be easily mass produced as they have a short generation time, and successfully released in biological control programs in cotton (King et al., 1986; Romeis and Shanower, 1996). There is a stronger needs to increase the activity of *Trichogramma* spp. in diversifying the agroecosystems (Kamp and Simons, 1978; Altieri et al.,1981). Present investigation showed attraction of adults of *H. armigera* to the panicles of sorghum from flowering through soft dough stage, with a peak egg density in the former and rapid decline in the latter stage confirming the earlier reports (Parsons, 1940; Pawar et al., 1989; Duffield, 1994a, b; Romeis et al., 1999; Parker and Scholz, 2004). The population of *T. chilonis* increased proportionately with the rate of oviposition by *H. armigera* and remained high as long as the host crop was suitable for oviposition. There was no asynchrony in colonization of sorghum by *H. armigera* for oviposition and parasitism by *T. chilonis*, because asynchrony was regarded as one of the major factors limiting the effectiveness of natural enemies of *H. armigera* (Fitt, 1989). High parasitoid population on sorghum during flowering may be partly due to emission of volatiles from the panicles. Olfactometer studies also showed that volatiles emitted during these stages in sorghum enable not only to attract but also parasitize the eggs of *H. armigera* by *T. chilonis* (Romeis et al., 1997, 1999). There was a dramatic decline in the rate of parasitism by *T. chilonis* of 40.3% on sprayed and 10.7% on non-sprayed cotton. Egg parasitism increased as a consequence of inundative releases such as 50% by *T. pintoi* in Tajikistan (Middle Asia) (Kovalenkov, 1992); 68.4% by *T. confusum* in China (Zhou, 1988); 49.0% (Twine and Lloyd, 1982) and 76% by *T. pretiosum* in Australia (Scholz and Murray, 1994); and 12.7% by a mixture of *Trichogrammatoidea* spp. in Kenya in
cotton agroecosystem (van den Berg et al., 1993). Sorghum crop reaches maturity early relative to the intercrop of cotton, and this would result in large population buildup of *T. chilonsis*, and the natural enemies thus provide an influx to move onto the maturing stage of cotton (Fye, 1971; Fye and Carranza, 1972; ICRISAT, 1993). This indicates a unique relationship between sorghum and cotton, which makes sorghum as an ideal crop for the conservation and buildup of natural enemies (Krauter et al., 1998; Prasifka et al., 1999a, b; 2004).

Ecological theory predicts that pests find plants more easily if concentrated in a monoculture than grown in polycultures (Root, 1973), while increasing crop diversity often reduces pest infestation (Risch, 1983; Andow, 1991). An increased abundance and action of natural enemies in polycultures are responsible for reduced pest levels (van den Bosch and Stern, 1969). Jadhav et al. (2000) observed that the cotton grown juxtaposed to sorghum had significantly high level of *H. armigera* egg parasitism by *T. chilonis* than in a distant and monocrop. Similarly, the grain sorghum being a trap crop served as a sink for the population of *H. zea* on cotton (Andow and Risch, 1987; Tillman et al., 2002; Tillman and Mullinix, 2004). Yadav et al. (1985) found that the inundative releases of *T. chilonis* were effective in reducing the infestation of *H. armigera* on tomato and potato, but not on chickpea. Further, they also reported that the parasitoid did not survive at >38°C. Other intercrop combinations also supported the migration of predator population to cotton from corn and sorghum (Massey and Young, 1975). Virk et al. (2004) demonstrated that maize, sorghum, pearl millet, and marigold as trap crops have increased the parasitism efficiency of *T. chilonis* on cotton. These studies clearly demonstrate that sorghum as a row intercrop can be used as a sink for the buildup of parasitoid populations and subsequent shift after maturity to cotton and prevent *H. armigera* from reaching the economic threshold levels on cotton. Thus, it is important to select suitable crop diversity for a given microclimate and/or biotic situations, which greatly reduce the need of heavy reliance on insecticides particularly on cotton and legumes and their intercrops (Fitt, 1989). It is critical, therefore, to select the suitable plant diversity for a given microclimate and biotic and/or intercrop situation because the specific diversity beneficial in one region may be harmful in another. The challenge is to provide a means by which the farmer can attain a flexible response to pest attack.