Field-testing is an important step in evaluating natural enemies for biocontrol. To establish the potential of any candidate, convincing empirical demonstrations are essential (Cloutier and Bauduin, 1995). Predator abundance and/or species composition may be affected by cultivation practices, thereby increasing or diminishing predator's pressure (Sheehan, 1986; Russell, 1989; Andow, 1991 and Ramert, 1996).

Colonization involves modifying cropping practices to improve the action of biocontrol agents (Ridgway et al., 1977). By colonizing locally available natural enemies, it is possible to ascertain how they disrupt the stability of a pest to a non-economic level and help to sustain that level (Waage, 1992; Uthamasamy, 1995). In many crops, the most common genera of hemipteran predators include *Geocoris* spp. (Lygaeidae), *Nabis* spp. (Nabidae), *Orius* spp. (Anthocoridae), *Podisus* spp. (Pentatomidae), *Lygus* spp. (Miridae) as well as *Acanthaspis* spp. and *Rhynocoris* spp. (Reduviidae). They are either occasional visitors or they are not found throughout the entire crop season. The success of predators in such habitats is the result of adaptation that permits them to exploit the ephemeral habitat (Reding and Beers, 1996). However, natural predators alone can not reduce the pest populations to a level sufficient to prevent economic damage to crops and eliminate the use of insecticides.

Generalist predators, particularly predatory bugs, have been largely ignored due to perceived augmentation difficulties and lack of host specificity (King and Powell, 1992; James, 1994a; Grundy and Mealzer, 2002). However, augmentative release of hemipteran
predators has merit for pest suppression (Franz and Krieg, 1982; Bievier and Chauvin, 1992b; Hough-Goldstein et al., 1993; Ambrose, 2000a and Claver et al., 2003b).

In the environmental manipulation of augmentative technique, the crop is utilized as 'field insectaries' to increase the predator number or to make existing numbers more efficient (Bennison and Corless, 1993; Van Driesche, 1993). Mulches may be living or non-living (Akobundu and Poku, 1987) they have their origin in early agriculture where covering soil and plants with organic or inorganic matter was used to form a protective barrier against frost or warm soil to improve plant growth (DeVey, 1991). Mulching was also used to limit soil water evaporation to control weeds, to improve soil tilth and manage erosion as well as a means of controlling pest insects, pathogens and nematodes (Dent, 1995). Natural or synthetic coverings may encourage or discourage pests and natural enemies. Plastic mulches may exclude pests and natural (living or non-living) mulches may permit their control providing a suitable habitat for their natural enemies. Hay or straw, for example, provides habitat for spiders. Research in Tennessee, U.S.A. showed a 70% reduction in damage to vegetables by insect pests when hay or straw was used as mulch. This difference was due to spiders, which find mulch habitable compared to bared ground. Similarly, living mulches of various cloves in orchards can provide habitat for natural enemies (Potdar and Kakkar, 2001). It has been recently demonstrated in some crops that mulches can improve pest control through enhanced natural enemy action, colonization of predators and reduction in insecticide application (Stoner, 1993; Brust, 1994; Ramert, 1996; Claver et al., 2003b). Mulches include many types and colours of plastic, grass, bark, wood strips, straw, cover crop residues and other plant materials (Ramert, 1993; Hausammann, 1996; Stoner, 1997). A knowledge of extend yield loss caused by various pests in a cropping system provides baseline information which can be used to determine priorities for Research and Development. It can also be used to assess the likely cost of control. The relative importance of different pests in a system can be determined through the construction of a crop loss profile (Chiarappa, 1981). The present study reported the effect of mulching practices on pest
population, natural enemy population, damage ratting to the cotton by the pests and also in
the colonization and biocontrol efficiency of the released reduviid predator Acanthaspis
pedestris Stål.

Materials and Methods

A randomized complete block experiment with six replicates of each four sets of
treatment was conducted in an agriculture farm at Thiruthangal near Sivakasi (9° 72' N 77°
49' E; MSL + 106.7m) during winter season (November 2001 to March 2002) in a 0.2
hectare field. Treatment plots were randomized in to five blocks, each containing a mulch
and non-mulch treatment (control). Mulching materials were obtained from the farm were
spread as bundles on soil surface in between rows. The plots were of 3.75 x 7.0 m size and
1m buffer of bare earth on each side. Sufficient leaflet and sugarcane trash (an 8-10cm deep)
layer were applied by hand to cotton rows and furrows in mulch plots 1 week before the
appearance of flower buds. The number of pests and the predators on the plants were
recorded during the experimental periods by visually examining ten randomly chosen plants
from the rows of each plant. Irregularly broken piece of clay pots (≤10cm²) and stones
(≤13cm³) were placed on the ridges in each row (Plate 6a-e). The plants were irrigated and
fertilized when needed and insecticides were not applied the during experimental period.
Each plots received 25 (fourth, fifth nympha stages and adult A. pedestris (total 600) against
Helicoverpa armigera and Spodoptera litura. A. pedestris were placed singly on to the
terminal shoots of the plants in the experimental plots at evenly spaced locations using a
camel hair brush before 11.00hr.

A. pedestris was mass reared in the laboratory (temperature 30 ± 1° C; relative
humidity 75± 5%; photoperiod 12±1h) in plastic containers (1.5lit.) on larvae of Corcyra
cephalonica Stainton. The C. cephalonica was reared in plastic trough (30 x10cm) on wheat
flour (refer Chapter -V Mass Rearing).
To evaluate the biocontrol potential of predators in treatment and control plots, population of *H. armigera* on bolls and *S. litura* on leaves and flowers were examined from November 29 to Feb 24, in randomly selected 1m sections of cotton of each plot. Direct observations on predator population of grubs and adults of Coccinellids, *Callasoma* sp. (Carabidae), nymphs and adults of *Nabid* sp. *Geocoris* sp., (Lygaeidae), *Cantheconidia* sp. (Pentatomidae), *Rhynocoris* sp. and *Acanthaspis* sp. (Reduviidae) praying mantis (Mantodae) and spiders were recorded in the experimental field and assessed by lifting the mulching leaflets and trashes, shelters of stone, pot pieces and fallen leaves.

The number of pests and predators was transformed by log (x+1) before analysis. All data were analyzed with a two-factor analysis of variance (ANOVA). Visual estimates of damage to cotton flowers, leaves and bolls on ten plants per plot were made six times a week. The data was converted into percentage and subjected to statistical analysis. The bolls from the plot were plucked periodically and weighed to assess the yield. The yield data from each treatment were converted per hectare. The data were subjected to statistical analysis (DMRT).

Observations on the predator population of coccinellids (grubs and adults), carabids, reduviids and spiders were recorded in the experimental field. The kapas from the plot were plucked periodically and weighed to assess the yield. The yield data from each treatment were converted per hectare. The data were subjected to statistical analysis (DMRT).
Results

The released reduviids were found colonized in mulched (trash $\bar{X} = 1.21 \pm 0.24$; leaflet $\bar{X} = 2.30 \pm 1.38$; pot piece $\bar{X} = 3.08 \pm 1.84$ and stone $\bar{X} = 5.42 \pm 3.48$) plots. They were found significantly higher in number in stone laid plots ($P < 0.001$) whereas the population of soil predatory arthropods were significantly greater in plantain leaflet mulched plots and stone laid plots, than in trash mulched plots and pot piece laid plots and in control plots (Fig. 19).

From the month of June through July the predatory beetles and reduviids on soil and foliage in control and test plots were recorded. During this period carabid beetles were found in large number in both control and test plots (control $\bar{X} = 0.75 \pm 0.22$; trash $\bar{X} = 3.24 \pm 1.16$; leaflet $\bar{X} = 4.18 \pm 0.45$; pot piece $\bar{X} = 2.42 \pm 0.72$ and stone $\bar{X} = 4.25 \pm 0.73$) (Fig. 17).

The percentage of good quality cotton was also greater in plantain leaflet mulched plots (3,134.7kg/hec) and stone laid plots (3,286.2kg/hec) than in control plots. The yield of seed cotton was also significantly greater ($P < 0.01$) in leaflet mulched plots and stone laid ($P < 0.01$) plots than in control plots (Table 17).

Table 17. The seed cotton yields in mulched and control plots ($\bar{X} \pm SD$)

<table>
<thead>
<tr>
<th>Control</th>
<th>Mulched</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Trash</td>
</tr>
<tr>
<td>2873.6a</td>
<td>2952.2 ab</td>
</tr>
</tbody>
</table>

Values followed by different letters with in a column are statistically significant.
Fig. 17. Mean number of soil and foliage predators in control and test plots

Fig. 18. Mean number of predators on the cotton foliage in the control and the tested plots from Dec. 2001 to Jan. 2002.

Fig. 19. Mean number of carabids and reduvids on soil and foliage in control and test plots
6a. A view of the experimental plots

6b. Plot mulched with plantain leaves

6c. Plot mulched with sugarcane trash

6d. Plot mulched with pot pieces

6e. Plot laid with stones

Plate-6
Table 18. Impact of *A. pedestris* on *H. armigera* and *S. litura* population/5 cotton plants in the control and mulched plots (\( \bar{X} \pm SD \))

<table>
<thead>
<tr>
<th>Sampling dates</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>14 Dec</td>
<td>Control</td>
<td>Leaflet</td>
<td>Trash</td>
<td>Pot piece</td>
<td>Stone</td>
<td>Control</td>
<td>Leaflet</td>
<td>Trash</td>
<td>Pot piece</td>
<td>Stone</td>
<td></td>
<td></td>
</tr>
<tr>
<td>21 Dec</td>
<td>3.88±1.74</td>
<td>2.22±1.21</td>
<td>3.77±1.21</td>
<td>2.88±1.16</td>
<td>1.5±1.01</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>28 Dec</td>
<td>2.00±1.76</td>
<td>1.10±1.32</td>
<td>1.93±1.57</td>
<td>2.05±1.23</td>
<td>1.11±1.05</td>
<td>1.55±0.44</td>
<td>1.16±1.32</td>
<td>1.66±0.70</td>
<td>0.06±0.72</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>04 Jan</td>
<td>2.55±1.74</td>
<td>0.44±0.72</td>
<td>1.11±0.8</td>
<td>1.66±1.32</td>
<td>1.30±1.32</td>
<td>2.77±1.71</td>
<td>1.11±0.78</td>
<td>2.88±3.02</td>
<td>2.44±2.52</td>
<td>1.77±1.39</td>
<td></td>
<td></td>
</tr>
<tr>
<td>11 Jan</td>
<td>1.44±1.23</td>
<td>0.02±0.44</td>
<td>0.33±0.50</td>
<td></td>
<td></td>
<td>2.55±1.74</td>
<td>0.44±0.72</td>
<td>2.44±1.58</td>
<td>1.55±1.01</td>
<td>1.61±1.03</td>
<td></td>
<td></td>
</tr>
<tr>
<td>18 Jan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>2.00±1.05</td>
<td>0.02±0.87</td>
<td>1.55±1.01</td>
<td>1.36±1.05</td>
<td>0.33±0.5</td>
</tr>
<tr>
<td>25 Jan</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.66±0.78</td>
<td></td>
<td>0.06±0.70</td>
<td>0.02±0.44</td>
<td></td>
</tr>
</tbody>
</table>

98
Moreover, the cotton obtained from mulched plots was comparatively of good quality than that from control plots.

The *A. pedestris* took shelter under the mulches after they were released in the test plots, from Dec. 2001 to Jan. 2002. Among predators the soil inhabiting predators comprised 68% and the foliage inhabiting predators comprised 32%. Among them coccinellids were predominant than hemipteran predators. Soil and foliage insect predator populations were higher in leaflet and stone laid mulched plots followed by trash laid and pot piece laid mulched plots (Fig. 17 and 18).

*H. armigera* and *S. litura* population was lower in mulched plots than in control plots (Table 18). They were significantly fewer in stone and leaflet mulched plots than in control plots (P<0.05%).

**Discussion**

Natural field populations of insect predators and parasitoids alone, if undisturbed, can substantially reduce heliothine pest populations in cotton. Large proportions of heliothine eggs are consumed by predators, parasitized, or removed by rain and wind before hatching (Fletcher and Thomas, 1943; Fye, 1979; Nuessly, 1986). Fletcher and Thomas (1943) observed that 15.3–32.9% of tagged *Helicoverpa armigera* (Hübner), eggs on cotton were destroyed by predators. Ridgway and Lingren (1972) found that
Natural populations of predators helped maintain bollworm populations below destructive levels in cotton. Based on data reported by some of these authors and others (Quaintance and Brues, 1905, Bell and Whitcomb, 1964), Ridgway and Lingren (1972) estimated that 50–90% of heliothine eggs and larvae in cotton were consumed or parasitized by natural populations of insect predators and parasitoids. Additionally, abiotic factors (e.g., rain and leaf abrasion resulting from wind) can substantially contribute to heliothine mortality, particularly during the egg stage (e.g., Fletcher and Thomas, 1943; Fye, 1972; Nuessly, 1986).

*H. armigera* and *S. litura* population was lower in mulched plots than in control plots. Stoner (1993) also found that fewer larval pests in mulch than in non-mulch treatments. The difference in number of predators between mulched plots than in non-mulched plots did not appear until approximately 1-2 weeks after the application of mulch.

The activity of ground carabid beetles increased in trash mulched, leaflet mulched plot than in control plots. The lack of ideal conditions in pot piece and control plots for normal activity could have influenced the beetles to remain beneath the surface of mulches. Similar results were also reported by Brust (1994), who stated that the activity of carabid beetles might have coincide with the time of the pest larvae were wandering on the ground in search of pupation sites.

The released *A. pedestris* was also more active on the soil surface during December 2001 to January 2002 in the leaf mulched and stone mulched plots. The other treatment and control plots have not recorded any activity of *A. pedestris*. This pronounced activity of *A. pedestris* in mulched plots might be correlated with an increased availability of suitable hiding places with optimal humid conditions. Moreover, Tay and Bony (1989) reported that artificially placed ant nests in coca field encouraged predatory ants to stay and control the mirid *Helopeltis antonii* Signoret than in the control field.
The early season foliage predators dominated over the soil predators. The foliage predator's density began to differentiate between control and mulched plots; nearly 1-2 weeks after the plots were mulched. From December to January foliage predators were two to three times greater in mulched plots than in non-mulched plots. Moreover, Whitcomb and Bell (1964) stated that foliage predators were abundant in cotton at early season to feed on egg and young larvae.

Cotton boll damage was lowered in mulched plots. Similarly, Brust (1994) stated that natural enemies significantly reduced pest defoliation in mulched plots than in non-mulched plots. However, Zehnder and Linduska (1987) stated that reduced feeding damage in mulched plots was due to reduced habitat suitability for pest.

The difference in defoliation was reflected in the differences on the yield of cotton and its quality in non-mulched plots than in mulched plots. Zehnder and Evanylo (1988) and Brust (1994) also reported similar results in potato.

There was not one specific predator that was responsible for an overall reduction in cotton pests in mulched plots. Instead, it was a complex of general predators, which constitution changed throughout the growing season that reduced the cotton pest population and their damage. Moreover, carabids and *A. pedestris* were most active and abundant predators on the soil surface during the late season. Hence their predation would have certainly helped to reduce the density of the upcoming second generation of *S. litura* and *H. armigera*. Further studies on the searching behaviour and nesting habits of these predators will enable one to effectively utilize them.