# Chapter - III

# Materials and Methods

# MATERIALS AND METHODS

## 3.1 Site of Investigation

The experiments were conducted in the Instructional Farm and Research Laboratory, Department of Agricultural Entomology, Bidhan Chandra Krishi Viswavidyalaya, North Bengal Campus, Pundibari, Cooch Behar, West Bengal, India.

## 3.2 Geographical Location, Soil and Climate

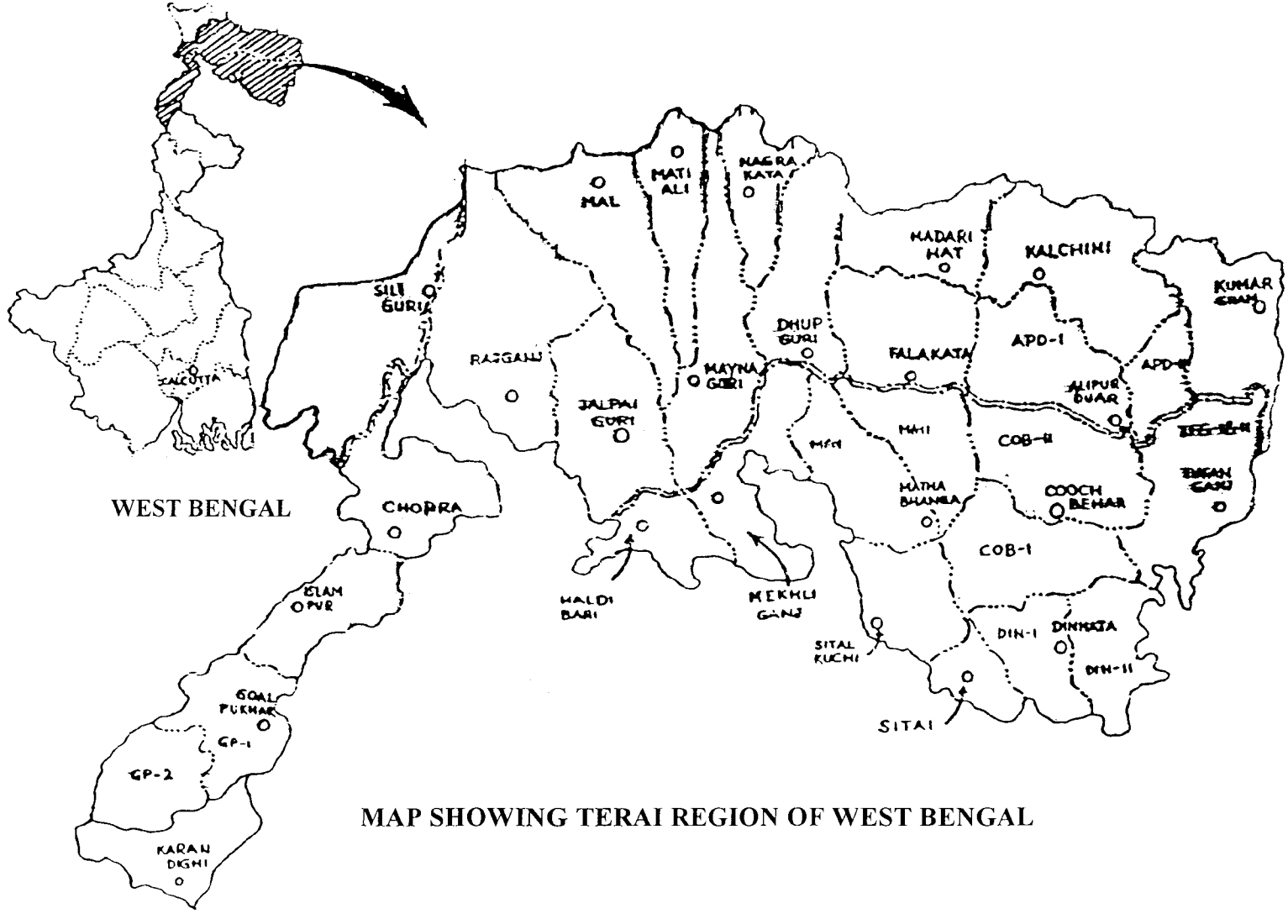
**Location :** Terai zone is situated between 25°57/ and 27°N latitude and 88°25/ and 89°54/ E longitude. This northern region of West Bengal is situated along Kurseong and Kalimpong hills and Bhutan hills in the north, Bihar border on the West and Assam border on the East. It includes Siliguri Sub-division of Darjeeling district and entire districts of Jalpaiguri and Cooch Behar and Islampur sub-division of North Dinajpur district. The total geographical area of the zone is 12025 sq. km. Which is 13.5% of the state area with 9.7% of the states population. Rural population comprises more than 90% of the population of the zone.

**Soil :** The soils of this zone can be classified into two broad tracts

**a) Old Himalayan piedment plains** – It spreads along with northern part of the area from Kharibari – Phanisidewa in the West to Kumargram in East covering northern part of Siliguri sub-division and Jalpaiguri district. Soils are sandy loam to loam type, formed mostly from the Himalayan detritus. This area has a dark brown top soil, 1 – 3 ft. deep, medium to strong acidic in nature and fairly rich in humus content. Available $N_2$, available $P_2O_5$ and available $K_2O$ contents are low to medium.

**b) Teesta flood plain** - It spreads along the southern portion of Siliguri sub-division and Jalpaiguri district and entire Cooch Behar district. Soil texture vary from sandy to silty clay loam. Most soils of the zone have high fixing capacity for phosphorus. Soils being grilty and porous and poor in secondary micronutrients.

**Climate :** The climate of the zone is sub-tropical humid. Average annual rainfall of this zone varies from 2100-3000mm. The maximum rainfall *i.e.* about 80% is received from south-west monsoon during the rainy months of June to September. While the range of minimum temperature of the area is 7-8°C that the maximum temperature is 24 – 33.20°C. The relative humidity of the area at 8.30 hour is 58% to 87% in March and July respectively. The relative humidity in the afternoon at 17.30 hour is 48% to




MAP SHOWING TERAI REGION OF WEST BENGAL

84% in March to November respectively. As a result the area as a whole is humid and warm climate except of having a short cold spell in winter, from December to February. The weather parameters during the period of investigation are furnished in Tables 3.1-3.4.

**Table 3.1 Weather parameters during the period of investigation in field condition in 1996-97**

| Standard Week | Temperature$^0$C | | | | Relative humidity % | | | | Average sunshine hr/day | Total Rainfall mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Gradient | Average | Maximum | Minimum | Gradient | Average | | |
| 49 | 27.61 | 11.74 | 15.87 | 19.67 | 90.71 | 37.14 | 53.57 | 63.93 | 7.43 | 0.00 |
| 50 | 26.74 | 11.40 | 15.34 | 19.07 | 89.71 | 36.57 | 53.14 | 69.29 | 7.57 | 0.00 |
| 51 | 26.29 | 10.41 | 15.88 | 18.35 | 90.43 | 41.00 | 49.43 | 65.07 | 7.42 | 0.00 |
| 52 | 25.87 | 10.24 | 15.63 | 18.06 | 92.00 | 37.22 | 54.78 | 64.94 | 7.52 | 0.00 |
| 1 | 22.51 | 9.40 | 13.11 | 15.95 | 95.86 | 47.00 | 48.86 | 71.43 | 6.61 | 0.00 |
| 2 | 20.28 | 9.60 | 10.68 | 14.94 | 94.71 | 50.14 | 44.57 | 72.42 | 5.31 | 0.00 |
| 3 | 21.81 | 9.10 | 12.71 | 15.45 | 94.86 | 56.00 | 38.86 | 75.43 | 4.30 | 3.00 |
| 4 | 20.57 | 8.13 | 12.44 | 14.35 | 95.00 | 48.50 | 46.50 | 71.75 | 3.60 | 0.00 |
| 5 | 21.63 | 10.24 | 11.39 | 15.93 | 95.43 | 59.43 | 36.00 | 77.43 | 5.30 | 2.80 |
| 6 | 22.06 | 10.76 | 11.30 | 16.41 | 92.14 | 51.14 | 41.00 | 71.64 | 6.84 | 0.00 |
| 7 | 25.08 | 10.80 | 14.88 | 18.24 | 95.71 | 43.14 | 52.57 | 69.42 | 8.18 | 0.00 |
| 8 | 26.10 | 10.17 | 15.93 | 18.13 | 92.43 | 37.86 | 54.57 | 65.14 | 8.63 | 0.00 |
| 9 | 29.00 | 13.00 | 16.00 | 21.00 | 86.71 | 36.71 | 50.00 | 61.71 | 8.41 | 8.60 |
| 10 | 31.01 | 16.28 | 14.73 | 23.64 | 89.45 | 41.00 | 48.45 | 65.22 | 9.07 | 0.00 |
| 11 | 31.51 | 16.76 | 14.75 | 24.13 | 88.14 | 41.28 | 46.86 | 64.71 | 9.35 | 0.00 |
| 12 | 30.36 | 15.87 | 14.49 | 23.11 | 91.10 | 50.60 | 40.50 | 70.85 | 9.43 | 0.00 |
| 13 | 29.23 | 16.34 | 12.89 | 22.78 | 91.55 | 53.73 | 37.82 | 72.64 | 5.70 | 98.5 |
| 14 | 28.10 | 16.81 | 11.29 | 22.45 | 92.00 | 56.86 | 35.14 | 74.83 | 4.90 | 77.20 |
| 15 | 27.64 | 16.28 | 11.36 | 21.96 | 87.71 | 59.71 | 28.00 | 73.73 | 5.98 | 7.40 |
| 16 | 26.64 | 16.60 | 10.04 | 21.64 | 87.14 | 63.86 | 23.28 | 75.50 | 6.08 | 19.60 |
| 17 | 29.84 | 19.15 | 10.69 | 22.99 | 84.78 | 57.33 | 27.45 | 71.05 | 8.44 | 25.70 |
| 18 | 32.73 | 21.18 | 11.55 | 26.95 | 84.00 | 57.71 | 26.29 | 70.85 | 9.56 | 19.40 |
| 19 | 30.67 | 21.10 | 9.57 | 25.88 | 82.57 | 60.43 | 22.14 | 71.50 | 8.28 | 48.80 |
| 20 | 32.93 | 21.41 | 11.52 | 27.17 | 85.56 | 59.43 | 26.23 | 72.64 | 8.88 | 58.30 |
| 21 | 30.95 | 21.97 | 8.98 | 26.46 | 89.90 | 69.40 | 20.40 | 79.60 | 5.51 | 81.80 |
| 22 | 33.34 | 23.03 | 10.31 | 28.18 | 86.86 | 63.00 | 23.86 | 74.93 | 5.10 | 0.00 |

# Table 3.2 Weather parameters during the period of investigation in field condition in 1997-98

| Standard Week | Temperature°C | | | | Relative humidity % | | | | Average sunshine hr/day | Total Rainfall mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Gradient | Average | Maximum | Minimum | Gradient | Average | | |
| 49 | 21.23 | 12.27 | 8.96 | 16.75 | 96.00 | 67.71 | 28.29 | 81.25 | 5.74 | 0 |
| 50 | 23.11 | 9.96 | 13.15 | 16.53 | 98.14 | 47.28 | 50.86 | 72.71 | 1.84 | 10.60 |
| 51 | 23.67 | 10.14 | 13.53 | 16.90 | 95.50 | 46.37 | 49.13 | 70.93 | 5.17 | 0 |
| 52 | 21.05 | 9.70 | 11.35 | 15.37 | 94.86 | 47.14 | 47.72 | 71.00 | 8.48 | 0 |
| 1 | 18.43 | 9.26 | 9.17 | 13.84 | 96.57 | 78.00 | 18.57 | 87.28 | 2.47 | 0 |
| 2 | 17.83 | 9.67 | 8.16 | 13.75 | 96.28 | 65.00 | 31.28 | 80.64 | 2.03 | 0 |
| 3 | 20.74 | 9.13 | 11.61 | 14.93 | 95.57 | 56.28 | 39.29 | 75.93 | 3.49 | 0 |
| 4 | 22.76 | 9.36 | 13.40 | 16.06 | 95.00 | 44.57 | 50.43 | 69.78 | 6.48 | 0 |
| 5 | 23.33 | 9.26 | 14.07 | 16.29 | 95.86 | 46.14 | 49.72 | 71.00 | 6.98 | 0 |
| 6 | 24.37 | 9.81 | 14.56 | 17.09 | 95.28 | 40.14 | 55.14 | 67.71 | 8.71 | 0 |
| 7 | 27.24 | 12.08 | 15.16 | 19.66 | 94.71 | 41.86 | 52.85 | 68.28 | 7.39 | 0 |
| 8 | 26.80 | 13.38 | 13.42 | 20.09 | 94.28 | 48.43 | 45.85 | 71.36 | 8.57 | 4.00 |
| 9 | 27.17 | 12.77 | 14.40 | 19.97 | 96.00 | 41.71 | 54.29 | 68.86 | 8.88 | 6.00 |
| 10 | 27.71 | 13.97 | 13.74 | 20.84 | 84.28 | 39.28 | 45.00 | 61.78 | 9.21 | 0 |
| 11 | 27.06 | 14.43 | 12.63 | 20.74 | 87.00 | 47.43 | 39.57 | 67.21 | 8.51 | 0 |
| 12 | 27.47 | 16.43 | 11.04 | 21.95 | 88.00 | 53.57 | 34.43 | 70.78 | 6.37 | 67.50 |
| 13 | 25.97 | 15.84 | 10.13 | 20.91 | 86.28 | 57.17 | 29.11 | 71.72 | 4.08 | 48.60 |
| 14 | 29.93 | 15.70 | 14.23 | 22.81 | 90.86 | 53.28 | 37.58 | 72.07 | 6.30 | 12.70 |
| 15 | 28.78 | 15.41 | 13.37 | 22.10 | 92.71 | 57.14 | 35.57 | 74.93 | 6.91 | 57.00 |
| 16 | 27.68 | 17.04 | 10.64 | 22.36 | 95.00 | 71.86 | 23.14 | 83.43 | 3.13 | 65.00 |
| 17 | 32.01 | 20.11 | 11.90 | 26.06 | 91.14 | 59.57 | 31.57 | 75.36 | 8.53 | 48.60 |
| 18 | 31.97 | 20.98 | 10.99 | 26.48 | 90.57 | 63.57 | 27.00 | 77.07 | 7.80 | 39.10 |
| 19 | 33.38 | 23.50 | 9.88 | 28.44 | 90.57 | 67.14 | 23.43 | 78.86 | 8.34 | 39.00 |
| 20 | 34.78 | 24.36 | 10.42 | 29.57 | 89.00 | 61.57 | 27.43 | 75.28 | 9.98 | 9.80 |
| 21 | 33.36 | 23.56 | 9.80 | 28.46 | 92.28 | 65.14 | 27.14 | 78.71 | 7.11 | 175.20 |
| 22 | 31.76 | 22.97 | 8.79 | 27.36 | 92.57 | 74.57 | 18.00 | 83.57 | 6.51 | 162.40 |

**Table 3.3 Weather parameters during the period of investigation in field condition in 1998-99**

| Standard Week | Temperature°C | | | | Relative humidity % | | | | Average sunshine hr/day | Total Rainfall mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Gradient | Average | Maximum | Minimum | Gradient | Average | | |
| 49 | 28.43 | 14.60 | 13.83 | 21.52 | 94.28 | 52.43 | 41.85 | 73.36 | 8.71 | 0 |
| 50 | 27.41 | 12.01 | 15.40 | 19.71 | 93.57 | 50.71 | 42.86 | 72.14 | 8.93 | 0 |
| 51 | 26.70 | 10.20 | 16.50 | 18.45 | 93.86 | 50.58 | 43.28 | 72.22 | 8.70 | 0 |
| 52 | 26.25 | 9.59 | 16.66 | 17.92 | 94.50 | 40.63 | 53.87 | 67.57 | 8.86 | 0 |
| 1 | 25.50 | 9.06 | 16.44 | 17.28 | 95.71 | 43.00 | 52.71 | 69.36 | 8.21 | 0 |
| 2 | 23.70 | 8.69 | 15.01 | 16.20 | 96.57 | 43.00 | 53.71 | 69.78 | 7.04 | 0 |
| 3 | 23.80 | 8.06 | 15.74 | 15.93 | 98.00 | 46.00 | 52.00 | 72.00 | 7.91 | 0 |
| 4 | 25.73 | 9.73 | 16.00 | 17.73 | 93.71 | 48.00 | 45.71 | 70.85 | 8.16 | 0 |
| 5 | 26.23 | 9.44 | 16.97 | 17.83 | 96.00 | 39.71 | 56.29 | 67.85 | 8.60 | 0 |
| 6 | 27.73 | 12.17 | 15.56 | 19.95 | 95.43 | 45.57 | 49.86 | 70.50 | 7.88 | 0 |
| 7 | 30.11 | 14.33 | 15.78 | 22.22 | 94.71 | 50.00 | 44.71 | 72.36 | 8.24 | 0 |
| 8 | 28.97 | 14.30 | 14.67 | 21.63 | 96.14 | 52.29 | 43.85 | 74.21 | 7.53 | 0 |
| 9 | 29.63 | 13.16 | 16.47 | 21.39 | 95.28 | 50.42 | 44.86 | 72.85 | 90.1 | 0 |
| 10 | 31.38 | 15.48 | 15.90 | 22.64 | 91.86 | 49.86 | 42.00 | 70.86 | 7.83 | 0 |
| 11 | 31.00 | 13.91 | 17.09 | 22.45 | 87.86 | 39.28 | 48.58 | 63.57 | 8.48 | 0 |
| 12 | 32.46 | 16.95 | 15.51 | 24.71 | 86.28 | 44.71 | 41.57 | 65.50 | 8.30 | 0 |
| 13 | 30.78 | 16.73 | 14.05 | 23.75 | 85.00 | 51.00 | 45.14 | 68.00 | 2.71 | 0 |
| 14 | 31.37 | 30.34 | 11.03 | 28.86 | 84.00 | 55.85 | 43.00 | 69.92 | 6.63 | 0 |
| 15 | 33.58 | 21.58 | 12.00 | 27.58 | 90.71 | 57.14 | 33.57 | 73.93 | 7.44 | 106.50 |
| 16 | 32.88 | 21.10 | 11.78 | 26.99 | 84.71 | 50.14 | 34.57 | 67.42 | 8.40 | 0 |
| 17 | 30.15 | 22.48 | 7.67 | 26.32 | 92.28 | 56.28 | 36.00 | 74.28 | 5.01 | 70.20 |
| 18 | 28.44 | 21.08 | 7.36 | 24.76 | 95.43 | 60.86 | 29.57 | 80.64 | 4.40 | 121.00 |
| 19 | 30.23 | 21.80 | 8.43 | 26.02 | 95.28 | 68.00 | 27.28 | 81.64 | 6.96 | 5.20 |
| 20 | 21.06 | 22.31 | 8.75 | 26.69 | 93.71 | 62.28 | 31.43 | 78.00 | 7.57 | 10.50 |
| 21 | 30.77 | 23.44 | 7.33 | 27.10 | 94.71 | 66.00 | 28.71 | 80.36 | 4.14 | 281.30 |
| 22 | 31.50 | 21.88 | 9.62 | 26.64 | 93.00 | 68.57 | 24.43 | 80.78 | 4.08 | 125.40 |

**Table 3.4 Weather parameters during the period of investigation in field condition (mean of three years).**

| Standard Week | Temperature°C | | | | Relative humidity % | | | | Average sunshine hr/day | Total Rainfall mm |
|---|---|---|---|---|---|---|---|---|---|---|
| | Maximum | Minimum | Gradient | Average | Maximum | Minimum | Gradient | Average | | |
| 49 | 25.76 | 12.87 | 12.89 | 19.31 | 93.66 | 52.43 | 41.23 | 73.04 | 7.30 | 0.00 |
| 50 | 25.75 | 11.12 | 14.64 | 18.44 | 93.81 | 44.85 | 48.96 | 69.33 | 6.11 | 3.53 |
| 51 | 25.55 | 10.25 | 14.97 | 17.74 | 93.26 | 43.55 | 44.71 | 68.41 | 7.10 | 0.00 |
| 52 | 24.39 | 9.84 | 14.55 | 17.12 | 93.79 | 46.07 | 47.72 | 69.33 | 8.29 | 0.00 |
| 1 | 22.20 | 9.24 | 12.96 | 15.72 | 96.05 | 59.24 | 46.81 | 77.64 | 5.77 | 0.00 |
| 2 | 20.75 | 9.32 | 11.43 | 15.03 | 95.85 | 52.71 | 43.14 | 74.28 | 4.80 | 0.00 |
| 3 | 22.08 | 8.76 | 13.32 | 15.42 | 96.14 | 52.76 | 53.36 | 74.45 | 5.90 | 1.00 |
| 4 | 22.33 | 9.07 | 13.26 | 15.70 | 94.57 | 47.02 | 47.55 | 70.79 | 6.08 | 0.00 |
| 5 | 23.73 | 9.65 | 14.08 | 16.69 | 95.62 | 48.43 | 47.19 | 72.02 | 6.96 | 0.93 |
| 6 | 23.78 | 10.91 | 12.87 | 17.35 | 95.38 | 45.62 | 49.76 | 70.50 | 4.53 | 0.00 |
| 7 | 27.37 | 12.40 | 14.97 | 19.89 | 94.04 | 45.00 | 49.04 | 69.52 | 7.94 | 0.00 |
| 8 | 27.12 | 12.62 | 14.50 | 19.87 | 94.33 | 46.19 | 48.14 | 70.26 | 8.24 | 1.33 |
| 9 | 28.19 | 12.97 | 15.23 | 20.58 | 94.09 | 42.94 | 51.15 | 68.51 | 8.77 | 4.87 |
| 10 | 29.81 | 15.24 | 14.57 | 22.52 | 89.09 | 43.38 | 55.71 | 66.23 | 8.70 | 0.00 |
| 11 | 29.80 | 15.03 | 14.77 | 22.42 | 87.38 | 42.66 | 44.72 | 65.02 | 8.78 | 0.00 |
| 12 | 30.56 | 16.42 | 14.14 | 23.49 | 88.43 | 49.63 | 38.80 | 69.03 | 8.03 | 22.50 |
| 13 | 28.64 | 16.30 | 12.33 | 22.47 | 87.66 | 53.97 | 33.69 | 70.81 | 4.17 | 49.03 |
| 14 | 29.94 | 17.58 | 12.36 | 23.76 | 88.48 | 55.33 | 33.15 | 71.90 | 5.94 | 29.97 |
| 15 | 30.00 | 17.77 | 12.23 | 23.89 | 90.38 | 58.00 | 32.38 | 74.19 | 6.78 | 56.97 |
| 16 | 29.47 | 18.35 | 11.12 | 23.91 | 88.43 | 61.95 | 26.48 | 75.19 | 6.30 | 28.20 |
| 17 | 30.67 | 20.34 | 10.13 | 25.60 | 85.52 | 57.73 | 27.79 | 71.62 | 7.33 | 48.17 |
| 18 | 30.98 | 21.08 | 9.90 | 26.03 | 90.09 | 60.71 | 29.38 | 75.40 | 7.25 | 59.83 |
| 19 | 31.51 | 22.01 | 9.51 | 26.76 | 89.66 | 65.19 | 24.47 | 77.42 | 7.86 | 31.00 |
| 20 | 32.88 | 23.83 | 10.05 | 27.85 | 88.76 | 61.09 | 17.67 | 74.93 | 8.81 | 26.20 |
| 21 | 31.47 | 22.69 | 8.78 | 27.08 | 93.28 | 66.85 | 26.43 | 80.06 | 5.59 | 179.43 |
| 22 | 31.97 | 22.60 | 9.37 | 27.29 | 90.52 | 68.71 | 21.81 | 79.62 | 5.23 | 95.93 |

## 3.3 Seasonal Incidence of Insect-Pests of Tomato and Their Natural Enemies

A commonly grown $F_1$ hybrid of tomato, Abinash-II, was raised from November to May during 1997-98 and 1998-99 to study the seasonal incidence and fluctuation pattern of population of insect-pests and their natural enemies and also the influence of prevailing environmental conditions on population dynamics. Twenty-one days old seedlings were transplanted four times on November 24, December 24, January 24 and February 24, with recommended fertilizer dose (130:65:65 kg. NPK/ha) and usual agronomic practices in 3m x 6m sized plots with 60cm x 75cm spacing as recommended by Pandita and Bhatnagar (1981) in both the years as mentioned above. There were six replications at par randomised block design (RBD). No plant protection measures were used for controlling insect-pests.

Observations of insect-pests and their natural enemies were recorded at seven days interval from the very time of their appearance on plants planted at different time. Ten plants were randomly selected from each replication for such observations. The insect-pests and natural enemies found active on tomato during the course of investigation were collected and identified by the scientists, Deptt. of Agril. Entomology, B.C.K.V., Pundibari, Cooch Behar and subsequently confirmed by the scientists of Zoological Survey of India, Calcutta, wherever, it was deemed necessary.

Observation of aphid and tingid bug population were recorded from 5 tender leaves per plant from 10 plants of each plot and were scored in number per leaf basis. The population of white fly, hadda beetle and the predatory population like *Menochilus*, *Coccinella* and spiders were recorded from 10 plants per plot and were counted as number per plant basis. Among the two internal feeders, leaf miner incidence was recorded by assessing per cent mined leaves per plant in 10 randomly selected plants per plot, whereas for fruit borer, fruits were plucked at different intervals when they attained marketable condition and the damaged fruits thus obtained from each harvesting were isolated, counted, weighed and thereafter calculated as percentage of damage both in number and weight.

Data thus obtained from all the four plantings of each of the two years were pooled. The peak attack on a particular planting and by a particular pest/natural enemy species was considered as the highest population among all the seasons (plantings).

In order to study the incidence and fluctuation of population and the influence of abiotic factors on the population build up of different insect-pests species and natural enemy population two approaches were adopted. Firstly graphical superimposition techniques were employed to study the effect of weather parameters prevailed during the season. Secondly, in order to study instantaneous impact of meteorological variables on the population build up of various insect-pest species and their natural enemies at different planting times and althrough the season, simple correlation studies were carried out. Factorial analyses were made to study the reaction of pest and natural enemy population structure and yield at different planting times and crop phenology.

## 3.4 Bio-Ecology of Important Insect-Pests of Tomato

This study was conducted only for fruit borer, leaf miner and white fly. The rearing was performed at different times of a year for a particular species.

### 3.4.1 Tomato fruit borer ( *Helicoverpa armigera* Hubner)

The larvae were collected from the affected fruits. The larvae so collected were reared in plastic jars (15cm x 10cm) and fresh tomato fruits were provided for feeding. The mouth of the jar was covered and secured with a piece of cloth and rubber band. Fresh fruits were given to the larvae daily just to avoid any fungal growth on damaged fruit, until the larvae abandoned the fruit for pupation. The pupae were collected and placed in a rearing glass jar provided with a piece of cotton soaked in water to maintain humidity. Moths on emergence from the pupae were collected and released in a glass jar (19cm x 15cm). The moths were fed on 5% honey solution soaked in cotton swab. Eggs were laid on the wall of the jar. Immediately after hatching, the larvae were shifted to tomato twig and thereafter to tomato fruits. The rearing process was repeated thrice and the duration of different developmental stages were recorded.

### 3.4.2 Leaf miner ( *Liriomyza trifolii* Burgess)

Tomato twigs bearing eggs were collected from the field. The twigs so collected were plugged with water soaked cotton at the cut end and kept in petriplates. The maggots on hatching entered and mined within the leaves where eggs were laid on and when attained full maturity they came out from the mined leaves and pupated in the floor of the petriplates. The pupae were kept in a culture tube. After emergence, the flies were collected and released

to pruned tomato plants bearing few leaves and raised in earthen pots covered with fine muslin cloth made cage. The adult flies were provided honey solution (5%) for feeding and laid eggs inside the leaves. The leaves containing eggs were then taken out of plant and the same procedure mentioned above was repeated four times. The duration of egg, larval, pupal adult and total life cycle was recorded.

### 3.4.3 White fly (*Bemisia tabaci* Gennadius)

Several flies were released into a tomato plant on earthen pot in cage made up of muslin cloth. After egg laying the adults were removed. The nymphs on emergence fed the leaves where eggs were laid. Before being active they passed some times in a mute condition, this stage was considered as the pupal stage. The flies then released to another plants and the duration of several developmental stages for four generations were recorded and pooled.

The important weather parameters, namely temperature and relative humidity under laboratory conditions during the period of studies were recorded daily. Data thus obtained from different developmental stages and life cycle in different generations in the different periods of crop growing season were correlated with prevailing weather parameters under laboratory conditions.

**Table 3.5 : Rearing room temperature and relative humidity during the period of study of life cycle**

| Month | Temperature (°C) | | | Relative humidity (%) |
|---|---|---|---|---|
| | Maximum | Minimum | Average | Average |
| October-1998 | 30.31 | 27.52 | 28.91 | 67.5 |
| November-1998 | 28.07 | 24.96 | 26.52 | 60.00 |
| December-1998 | 27.00 | 22.00 | 24.50 | 65.00 |
| January-1999 | 23.06 | 19.14 | 21.10 | 60.05 |
| February-1999 | 26.50 | 23.13 | 24.81 | 63.54 |
| March-1999 | 28.96 | 25.00 | 26.98 | 51.47 |
| April-1999 | 30.97 | 27.55 | 24.26 | 64.80 |

## 3.5 Assessment of Crop Loss of Tomato Caused by Important Insect-Pests

The investigation on the extent of damage and assessment of loss in yield due to insect-pests attack was carried out during 1996-97, 1997-98 and 1998-99, in two seasons, one during winter and another during spring-summer season. Two commonly grown varieties, open pollinated (Pusa

Ruby) and $F_1$ hybrid (Abinash-II) were transplanted once on 3rd week of November for winter crop and other on 2nd week of February for spring-summer crop respectively, in each of the year. The crops were raised with recommended fertilizer dose (130:65:65 kg NPK/ha) in large plots (4.8m x 6m) with 60cm x 75cm spacing at par randomized block design with six replications. In addition to control there were three treatments which were as follows :

$T_1$ = Insecticidal treatment. (Treated with carbofuran 3G in soil at 10 days after transplanting and subsequently sprayed with malathion @ 0.05% at an interval of 15 days after 30 days of application of carbofuran).

$T_2$ = Fungicidal treatment. (Sprayed with fungicide (Dithane M-45 @ 2gm/l of water) at an interval of 15 days).

$T_3$ = $T_1 + T_2$ (Full protection with insecticide and fungicide)

Observations of pests were made at 10 days interval from the very time of their appearance on plant. Ten plants were randomly selected from each plot for observation. Aphid and tingid bug populations were scored from five tender leaves of each plant. Population of white fly and predator like, *Menochilus sexmaculata, Coccinella septempunctata* and spider were recorded from 10 plants per plot and were counted in number per plant basis. Leaf miner incidence was recorded by assessing per cent of mined leaves per plant in 10 randomly selected plants per plot, where as, for fruit borer, the fruits were plucked at an frequent interval when they attained marketable conditions and the damaged fruits thus obtained from different plucking were isolated, counted, weighed and calculated into percentage of damage in number and weight. Yield of tomato of each treatment was recorded on the basis of total fruit weight and then converted into t/ha.

Data thus obtained were pooled and analysed statistically. For assessment of crop loss **'t'**-test was applied which involves a comparison of yields of two plots in each of the six replications, where the plants from one plot were protected from insect-pests/diseases/both pests and diseases, by 6 round of insecticide/fungicide/both insecticide and fungicide sprays after the appearance of pests, where the plants of other plots were allowed to damage by naturally occurring population of pests. Gain in yield over control was calculated by the following formula :

$$\textbf{Per cent gain in yield over control} = \frac{\textbf{Yield in treated plot} - \textbf{Yield in controlled plot}}{\textbf{Yield in treated plot}} \times 100$$

## 3.6 Evaluation of Tomato Varieties against Insect-Pests, Natural Enemies and Yield

After a through survey in different parts of terai region of West Bengal, seven varieties most commonly cultivated in this zone namely, Kubergeeta (hybrid), Arjuna (hybrid), Divya (hybrid), Rupali (hybrid), Rasika (hybrid), Abinash-II (hybrid) and Pusa Ruby (open pollinated) were selected and raised during 1996-97, 1997-98 and 1998-99 to evaluate against insect-pests and natural enemies. All the varieties were transplanted on 19th November in each of the year with a spacing of 60cm x 75cm. Each variety was planted in row and replicated six times in six rows in randomized block design to obtain uniform dispersal effect of the pests and natural enemies among the varieties.

Observations on major insect-pest species and natural enemies were made at 7 days interval at the very time of their appearance on the crop. Aphid population was recorded from 5 tender leaves (where concentration of aphid population was maximum) per plant from 10 plants per plot and converted them into number per leaf, whereas, white fly and natural enemies like *Menochilus* and spider population was counted in population per plant basis, from 10 plants per plot. Leaf miner incidence was recorded in the form of per cent mined leaves per plant. Fruit borer (infestation) percentage was calculated from the percentage of damaged fruit (in number and weight) among the fruits plucked at every harvesting. Yield of different varieties were recorded on the basis of total fruit (cumulative of all plucking) and then converted into ton per hactare. Total number of fruits and numbers of bored fruit produced per plant were recorded and average of each variety was calculated from randomly selected plants. Mean weight of marketable fruits was recorded from each plucking of each variety in each replication and averaged in gram per fruit. Data thus obtained were pooled and analysed statistically (Factorial analysis).

## 3.7 Management of Insect-Pest Complex of Tomato through Pesticides

This aspect of study was confined only to Abinash-II hybrid. The crop was raised with agronomic practices stated in previous experiment in 4.5m x 1.8m sized plot with three replications at par RBD layout. The seedlings were transplanted on 15th February in each of the three year (1996-97, 1997-98 and 1998-99). Seven pesticides (Table 3.6) namely, two synthetic insecticides usually recommended for vegetables (malathion and DDVP), one

neem based pesticide containing azadirachtin, three entomopathogens (*Bacillus thuringiensis* var. *kurstaki*, *Beauveria bassiana* and nuclear polyhedrosis virus) and a microbial toxin from a soil actinomycetes, *Streptomyces avermitilis*, avermectin were taken with a view to evaluate their efficacy at the field level. First spray was given with the initiation of infestation. Subsequent sprays were made at 15 days interval. Therefore, 3 rounds of spray as required were made during the period of investigation for each year.

**Table 3.6 Informations on different pesticides evaluated under the programme.**

| | Pesticides | Doses |
|---|---|---|
| 1. | Malathion | 0.05% ai |
| 2. | DDVP | 0.05% ai |
| 3. | Azadirachtin | 1500 ppm ai |
| 4. | *Bacillus thuringiensis* var *kurstaki* (Bt)(5 x $10^7$ spores/mg) | 1.0 g/l |
| 5. | *Beauveria bassiana* (a pathogenic fungus) | $10^7$ conidia/ml |
| 6. | Ha NPV (Nuclear Polyhedrosis Virus) | 250 LE/ha |
| 7. | Avermectin (a microbial toxin from soil actinomycetes) | 0.01% ai |

Observations on population of major insect-pests and their natural enemies were taken once before spraying and then after 3, 8 and 14 days of spraying. Observations on pest population and natural enemy populations were taken as mentioned in earlier experiments in 3, 8 and 14 days after each spraying. Fruit borer infestation was calculated in per cent damaged fruit in number and weight out of all the fruits plucked at every harvesting, at frequent interval as and when attained marketable condition. Yield of marketable produce was calculated in different years separately on the basis of fruit yield per plot and converted to ton per hactare.

For the purpose of studies on comparative efficacy, percentage of incidence was converted into percentage protection (efficacy) by using following parameters :

$$\textbf{Per cent protection} = \frac{\textbf{Per cent protection in treatments} - \textbf{Per cent protection in control}}{\textbf{100} - \textbf{Per cent protection in control}} \times \textbf{100}$$

Data thus obtained from three years were pooled and analysed statistically.