# 1. INTRODUCTION

The Darjeeling district of West Bengal (Fig.1) is located between 26°31′ and 27°13′ North latitude and between 87°59′ and 88°53′ East longitude covering an area of 3149 sq. km. Northern part of the district has the distribution of Eastern Himalayan range and the Southern part has a stretch of alluvial plain at the base of the hills which is known as terai (Fig.2). In this exclusive agro-climatic region an experimental study on egg plant was carried out.

## 1.1. Introduction to *Solanum melongena* L. (brinjal or egg plant)

*Solanum melongena* L. is one of the 900 species of the genus *Solanum* having high economic value. Popularly the species goes by the names : egg plant (Fig.3), brinjal, Guinea squash and aubergine. It is believed to have originated in Indo-Burma. China may be the secondary centre of origin.

Among the solanaceous vegetables, brinjal is extensively grown in India and is very well appreciated vegetable among people of all social and economic strata. It is grown both in home and in market gardens. Several varieties of this crop are cultivated throughout the year. It is also popular in several other countries like, Bangladesh, Pakistan, Japan, Indonesia, Philippines, China, Bulgaria, France and Italy and to some extent in some tropical countries of Africa and America.

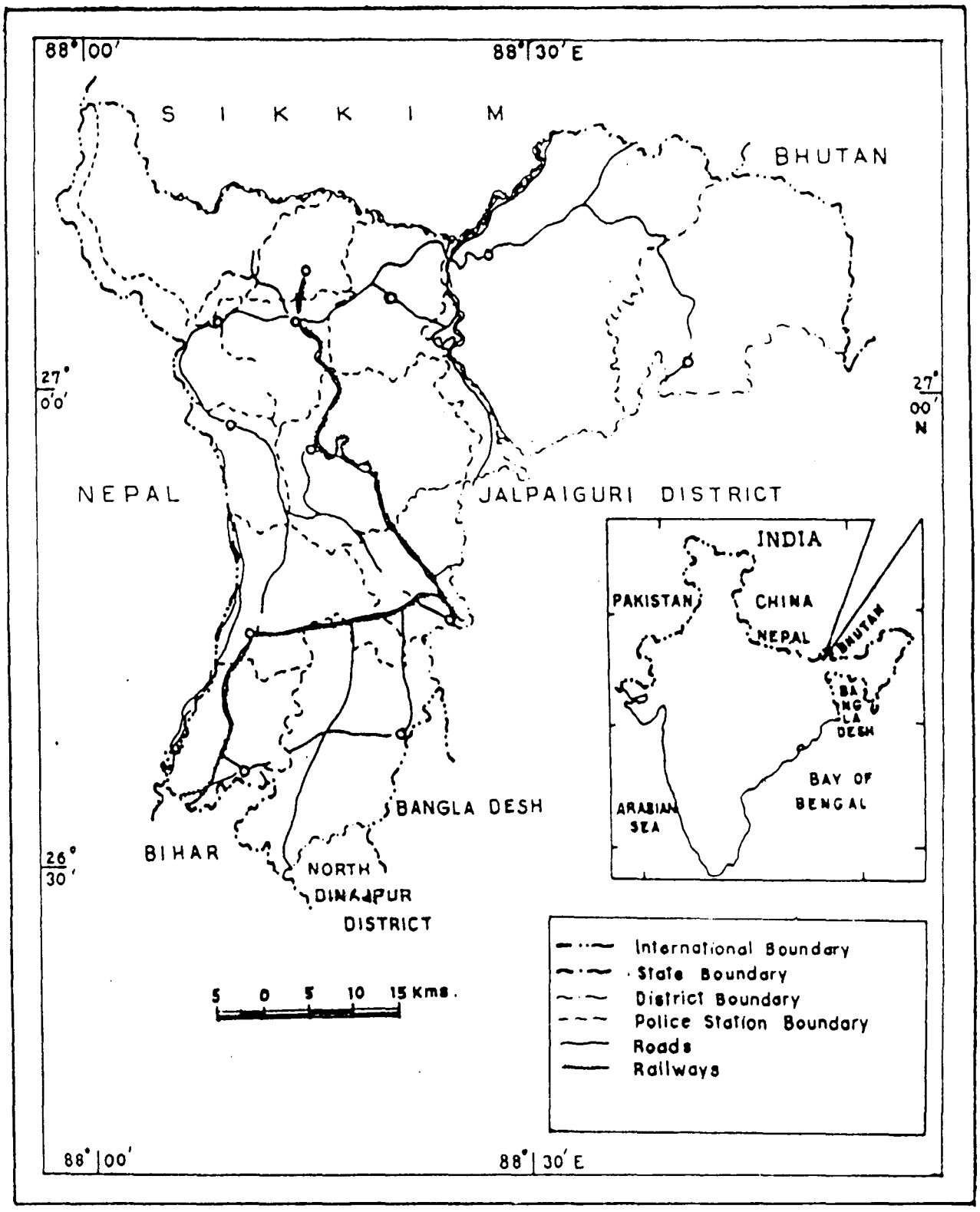


Fig.1. Map showing location of district Darjeeling

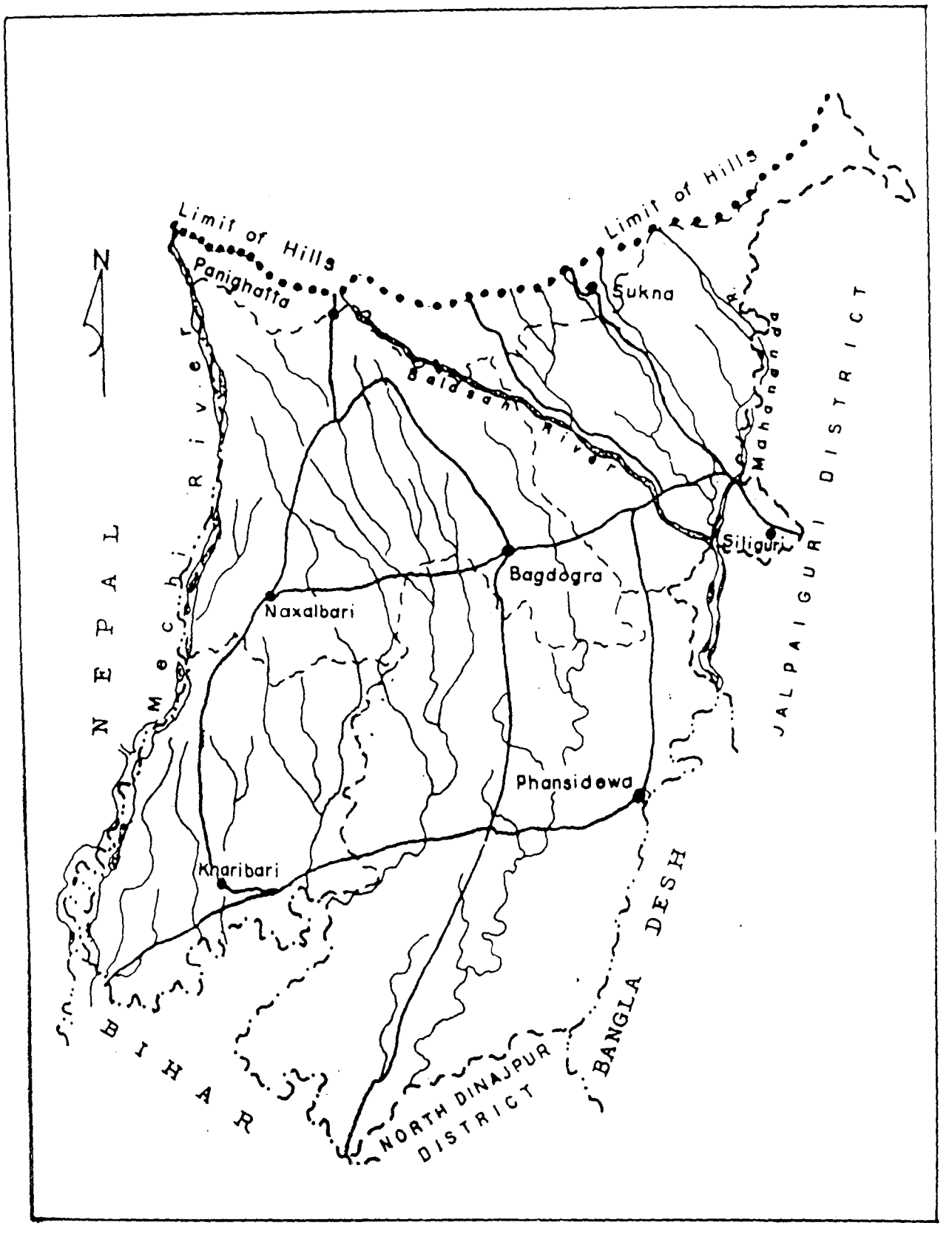


Fig.2. Map showing Darjeeling plain with roads police stations and rivers.

Brinjal is a major commercial vegetable crop and is grown all over India except at high altitudes (Wesley, 1956). It is also one of the common cash vegetables of West Bengal, in almost all the districts, and in both urban and rural areas.

It is a herbaceous annual plant with an erect and semi-spreading habit. The fruit is berry, borne singly or in clusters.

Brinjal has been a staple vegetable in our diet since ancient times. It is liked by both poor and rich. Contrary to the common belief, it is quite high in nutritive value and can be compared with tomato. The chemical composition of brinjal per 100 gm of edible portion contains 1.4g protein, 0.3g fat, 4.0g carbohydrate and 12 mg vitamin C along with vitamin B-complex and other ingredients. So, it is the proven fact that brinjal is a nutritious vegetable. The fruits are supposed to contain certain medicinal properties (Hemi, 1955).

The present market demand for vegetable particularly brinjal has increased (Fig.4) considerably leading to an increase in land area for the crop (Fig.5). With the increase in cultivation of brinjal, both during Kharif and during Rabi seasons incidences of brinjal pests have also increased considerably. Hence, insect pest attack is considered as an important factor limiting the successful cultivation of this crop. Some of the important insect pest that attack brinjal are the shoot and fruit borer, epilachna beetle, jassids, mites, leaf roller, stem borer, mealy bug, aphids, bud worm, lace wing bug etc.

Among these, the brinjal shoot and fruit borer, *L. orbonalis* Guen. (Pyralidae : Lepidoptera) is considered as the key pest of brinjal. It causes

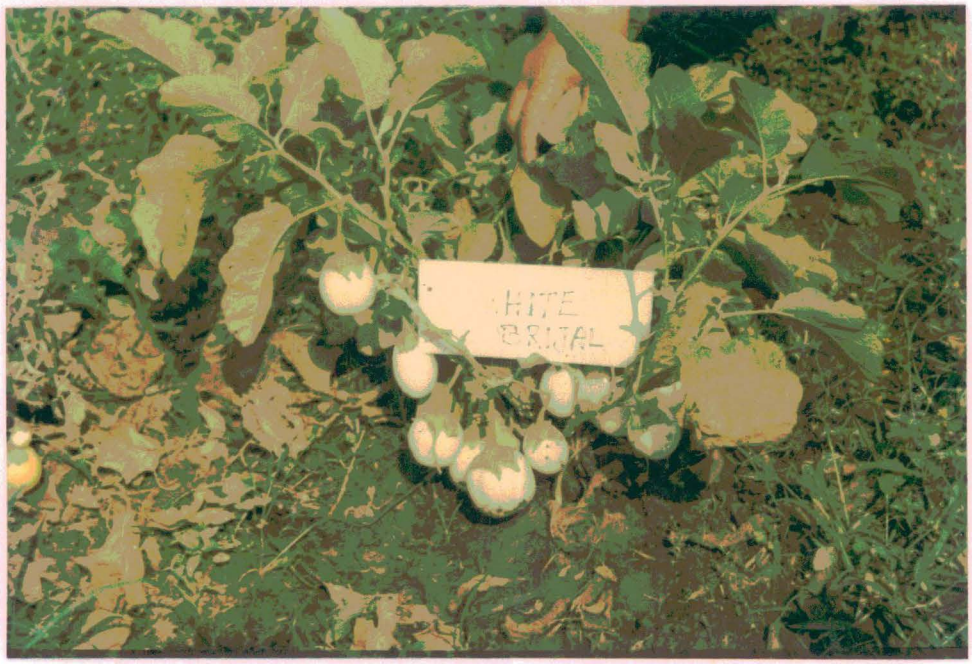


*Fig. 3. An egg plant (Solanum melongena* L.)

*Fig. 4. A market view of North Bengal showing importance of brinjal*

*Fig. 5. A brinjal field of North Bengal*

*Fig. 6. Full grown larva of Leucinodes orbonalis (Guen.)*

*Fig. 7. Borer infested brinjal fruits showing exit holes*

*Fig. 8. Infested brinjal fruits showing tunnels due to consumption of internal tissue by the borer (Leucinodes orbonalis)*

serious damage to the plant and fruit every year. Boring a fruit by a single larvae causes almost total loss of market value of the fruit though the larva itself consumes only a very little portion of it. The other major pests are the jassid, *Amrasca biguttula biguttula* (Ishida), the cotton aphid, *Aphis* gossypii (Glover), and the epilachna beetle, *Epilachna vigintioctopunctata* (Fab).

Because of high demand of brinjal in the market and because of its short supply and also for good market value, farmers, therefore, want to keep the crop pest free. Hence to get a better economic return from their produce, farmers are seeking assistance from technical personel to combat the pest and to prevent the loss in yield particularly due to attack of shoot and fruit borer.

## 1.2. Nature and symptoms of damage caused by four major pests of brinjal

**Shoot and fruit borer :**

*Leucinodes orbonalis :* The shoot and fruit borer, *L. orbonalis* Guen is the key pest of brinjal. This most important and destructive insect enjoys a country wide distribution. The damage is done by caterpillars which are creamy white when young, but light pink (Fig.6) when full grown. They measure about 18-23 mm in length. The moth is white but has pale brown or black spots on the dorsum of the thorax and abdomen. Its wings are white with a pinkish or bluish tinge and are ringed with small hair along the apical and anal margins. The forewings are ornamented with a number of black, pale and light brown spots. The moth measures about 20-22 mm across the spread wings (Atwal, 1986).

During their life span of 2-5 days, the moths lay 80-120 creamy white eggs, singly or in batches of 2-4 on the under surface of leaves, on green stems, flower buds or the calyces of fruits. The larva is a borer of tender shoot, leaf mid-rib, petiole and fruits and feeds on the internal tissue. A full-fed and grown larva becomes stout and pink coloured. One larva may destroy as many as 4-6 fruits. The larva grows through 5 stages and are full-fed in 9-28 days (Atwal, 1986). The mature larvae come out of their feeding tunnels and pupate in tough silken cocoons among the fallen leaves. The pupal stage lasts for 6-17 days and the life-cycle is completed in 20-43 days during active season. There are 5 overlapping generations in a year.

The pest starts attacking brinjal from a few weeks after its transplantation. When the shoot is infested by the caterpillar it droops and withers away and finally dries up. When the petioles of the leaves are bored the leaves wither and droop. The attacked fruit show holes being pluged with excreta (Fig.7).

The genus *Leucinodes* includes three species namely, *L. orbonalis* Guen., *L. diaphana* Hampson and *L. apicalis* Hampson. This pyralid pest is found to be associated with a number of host plants like potato, brinjal (Kadam and Patel, 1956) *Solanum xanthocarpum, S. indicum S. nigram,* bitter gourd and pea pods.

Brinjal suffers from damage by various pests of which *L. orbonalis* causes serious damage to the plants and fruits (Fig.8) every years, either sporadically or in epidemic form in West Bengal. According to Hemi (1955), the content of Vitamin C (Ascorbic acid) of brinjal fruits is reduced by 68% due to attack of this pest.

*Fig. 7. Borer infested brinjal fruits showing exit holes*

*Fig. 8. Infested brinjal fruits showing tunnels due to consumption of internal tissue by the borer (Leucinodes orbonalis)*

Banerjee and Basu (1956) and Srinivasan and Basheer (1961) have reported that the infestation by *L. orbonalis* on brinjal crop starts after a few week following transplantation which results in withering of leaves, fruits, buds and shoots. The infestation on brinjal can be as high as 70%. Dhankhar *et al.* (1977) also reported as high as 54% yield loss from Haryana. About 40-70% loss in production has also been reported by Panda *et al.* (1976). Mandal *et al.* (1994) and Mukhopadhyay and Mandal (1994) reported 11.76 to 52.73% yield loss in the rabi season in North Bengal Terai region of the Darjeeling foot hills.

**Jassid :**

*Amrasca biguttula biguttula* (Ishida) : This is another important pest of brinjal. Both nymphs and adults suck the sap from the lower surface of the leaves. The infested leaves curl upwards along the margins which may turn yellowish and show burnt up patches. The pest also transmits mycoplasma disease like tissue leaf and virus disease like mosaic. Fruit setting is adversely affected by the infestation.

Among the various pests of brinjal the cotton jassid *A. biguttula biguttula* is one of the most important hemipteran pest, causing serious damage by sucking cell sap.

Both adults and nympths of the jassid species suck sap from the leaves and transmit various type of viruses that cause mosaic diseases in brinjal.

Egg plant is infested by about a dozen of different species of leaf hoppers in different tropical and subtropical countries (Mahal, 1975). In India, it suffers greatly from the attack by the polyphagous jassid, *A. biguttula biguttula*.

**Aphid :**

*Aphis gossypii* Glover : It is a polyphagous species infesting a large number of plants throughout India. The aphid is small, soft, yellowish green or greenish brown and is found in colonies of hundreds on the tender shoot and the under surface of tender leaves. Both nymph and adults suck the sap of the leaves. In case of severe attack, the affected leaves curl, fade gradually and finally dry up. Black sooty mould grows on the honey dew excreted by the aphid and falling on the leaves, that adversely affects the photosynthesis resulting in the arrest of plant growth and reduction in fruit size (Bose, Some and Kabir, 1993).

The aphid, *Aphis gossypii* of the order Hemiptera is one of the most important pests causing damage to the cultivated crops. Both adults and nymphs of this pest suck sap from leaves and transmit various types of virus and mosaic diseases. Among the vegetable crops brinjal is severely affected by aphid pest particularly during pre-flowering stage.

*A. gossypii* is an important pest of eggplant causing extensive damage during pre-flowering stage of the crop. The preferred feeding sites were midribs, major veins, and the junction between petiole and lamina on the lower surface of young or early senescent leaves shoot apices and flower buds. (Cruz and Bernardo, 1971).

According to Chelliah (1973), damage potential of aphid in eggplant may be to the extent of 75.26% in shoot weight, 65.80% in root weight, 37.07% in shoot length and 23.68% in leaf number. Regupathy and Jayaraj (1973) noticed that occurrence of dark green form of aphids on brinjal were fewer in summer season and cold period of the year. Ueda and Takada

(1977) studied differential relative abundance of green yellow and red forms of aphids in relation to the food plant. They reported that the proportion of green yellow aphids was lowest on potato and egg plant in comparison to that of radish and cabbage.

**By Epilachna beetle :**

*Epilachna vigintioctopunctata* Fab : It is also a polyphagous insect that feeds on the leaves of potato, brinjal, tomato, etc. by scrapping, in a characteristic manner leaving the veins intact. The grubs are yellowish in colour and stout bodied with stiff hairs on their bodies. The beetle is bronze to red, small, spherical and mottled with black spots. In brinjal, the adult and grub feed voraciously on the leaves and tender parts of the plant and often cause serious damage when they appear in good numbers. As a result of feeding by both grubs and adults on green chlorophyll, characteristic skeletonized patches appear on leaves which later dry away.

The plant is severely affected by the attack of the beetle whose incidence have been found to be serious under West Bengal condition.

**1.3. Screening of brinjal germplasm against major insect pests**

To protect the crop from the depredation of these four insect pests, various chemical control measures have been suggested from time to time. Since, present control methods are not fully effective and are costly and ecotoxic, plant resistance may be combined as an effective measure to combat the menace caused by the pests and all the same overcoming the hazards associated with chemical control (Schalk, 1990).

The development, survival, biology etc. of a particular pest differ from place to place because of agroclimatic variations particularly with respect

to temperature and humidity. Further, growth and yield potentiality of different cultivars of brinjal are influenced by argoclimatic conditions. Combined effects of the abiotic factors on the pest species and the crop plant are crucial to determine the degree of tolerance of the plant against the pest. However, no information is available on this aspect of brinjal crop in the exclusive agroenvironment of Darjeeling foothills and plain. This prompted the author to undertake an investigation on brinjal pests from this area.

Considering other control practices, breeding of brinjal cultivars for insect pest resistance appeared to be one of the economic and ecofriendly means for sustainable brinjal productivity in the argoclimatic region of Darjeeling Terai. In the present investigation 41 common cultivars and lines of brinjal collected from different parts of India were screened to identify the varieties showing better yield and acceptability and at the same time showing certain degree of resistance against major insect pests in the area of study.

**1.4. Variability studies on different traits of brinjal cultivars**

This has got profound importance and utility for estimating genotypic and phenotypic variances and covariances for brinjal breeding programme. Specific objectives in relation to various traits are analysed by variability studies to estimate genotypic, phenotypic and genotype-environmental interaction variances among strains to utilize the preceding estimates to predict progress expected from selection and to construct and evaluate various selection indices.

The importance of genetic variability for resistance and wider adaptibility is well known. Moreover, the efficiency of selection, in plant breeding largely depends on the extend of genetic variability present in the plant population. Thus, insight into the magnitude of genetic variability is of paramount importance to a plant breeder for starting a judicious breeding programme. Finally, biological variation present in the plant population is of three type, viz., phenotypic, genotypic and environmental. (Singh and Narayanan, 1994).

**1.5. Correlation and path analysis of various traits of brinjal**

In plant breeding correlation coefficient analysis measures the mutual relationship between various plant characters and determines the component characters on which selection can be based for genetic improvement in yield.

Correlation coefficients are of 3 types, viz. (i) simple or total, (ii) partial and (iii) multiple correlation. These are again classified as phenotypic, genotypic and environmental correlations (Singh and Narayanan, 1993).

Correlation studies provides better understanding of yield components which helps the plant breeder during selection (Robinson *et al.* 1949; Johnson *et al,* 1955). There are 3 main implications of correlations in plant breeding as discussed below.

1. A positive correlation between desirable characters is favourable to the plant breeder because it helps in simultaneous improvement of both the characters. A negative correlation, on the other hand, will hinder the simultaneous expression of both the characters with high values. In such situations some economic compromise has to be made.

2. The genetic improvement, in dependent trait can be achieved by applying strong selection to a character which is genetically correlated with the dependent character. This is called correlated response.
3. Sometimes a character has low heritability. Under such situation another character having high heritability and high correlation with the former trait is chosen to make selection more effective. Thus genetic improvement is achieved using indirect selection through component characters with high heritability.

The concept of path analysis, also known as path coefficient analysis, was originally developed by Wright in 1921, but the technique was first used for plant selection by Dewey and Lu in 1959. Path coefficient analysis is simply a standardized partial regression coefficient which splits the correlation coefficient into the measures of direct and indirect effects. It measures the direct and indirect contribution of independent variables on dependent variables.

The path coefficient analysis is of three types - (i) phenotypic, (ii) genotypic and (iii) environmental paths. The phenotypic path splits the phenotypic correlation coefficients into the measures of direct and indirect effects. While the genotypic path is estimated from genotypic correlation coefficient. The environmental path is estimated from environmental coefficients. In plant breeding experiments the first two types of paths are in common use.

It provides the basis for selection of superior genotypes from the diverse breeding population.

## 1.6. Genetic divergence in brinjal

The concept of $D^2$ statistics was originally developed by P.C. Mahalanobis in 1928. Now this technique is extensively used in plant breeding and genetics for study of genetic divergence in various breeding materials. This is one of the potent techniques of measuring genetic divergence. In plant breeding, genetic diversity plays an important role because hybrids between lines of diverse origin generally, display a greater heterosis than those between closely related parents.

$D^2$ statistics finds out the contribution of individual character towards total divergence and groups the different genotypes into various cluster forming cluster diagram.

## 1.7. Judicious use of pesticides under IPM

With the consciousness of using the chemicals judiciously to minimize the pollution hazards, the scientists recommended the pests should be controlled by integrating and manipulating the biological factors with the use of insecticides. Based on this concept Bartlett (1956), coined the term 'Integrated Pest Control' which was defined as the blending of biological control agents with chemical control measures.

In line with the above philosophy, 3 spray schedules at 15 days intervals have been tried on the relatively tolerant local variety Dhepa to minimise the pest population below the economic threshold and also to find out the economically best pesticides in the times of need as well as to assess the degree of pest infestation when judicious application of agrochemicals or pesticides was made of an expectedly resistant cultivar in the exclusive climate of Darjeeling Terai.

## 1.8. Performance of parents and $F_1$ hybrids

The superiority of hybrids has been well demonstrated in a variety of important vegetable crops. Therefore, the demand for hybrid seeds will definitely increase. The main constraints in commercialization of hybrid cultivars are availability of hybrid seeds and its comparatively higher cost. Hybrid vgetables are well known in developed countries like Japan, the Netherlands, the USA and Canada where the vegetable seed industry, in general, is well organised and highly developed. Several workers have estimated that even with the present high cost of seed it is profitable to grow $F_1$ hybrids.

Though the possibilities of exploiting hybrid vigour in number of vegetable crops for higher, early and total yield, uniformity, in performance, environmental adaptation, resistance to diseases and insect-pests, and nutritional and processing qualities are well known, the work on heterosis breeding in vegetables in India needs to be strengthened and properly organised. The improvement programme of brinjal is oriented to develop new varieties which have disease resistance, insect pest resistance, high yielding potentiality, wider adaptibility and better quality fruits.

In order to achieve this objective, it is necessary to evaluate a large number of parents for their combining ability. The ability of parents to combine well depends upon complex interactions among the genes. So selection of potential parents for hybridization needs to be based on their complete genetic information and combining ability and not merely the yield performance of the different genotypes. Therefore, investigation was aimed at studying the combining ability and hybrid vigour of six selected brinjal parents in the exclusive climate of Darjeeling Terai.

## 1.9. Principal objectives of the present investigation

1. Screening of brinjal germplasm for resistance to major insect pests and selection of suitable variety having resistance or tolerance for sustainable production without any obligation for pesticides for the following reasons :

(i) to overcome the inadequacy of direct control measures in terms of efficacy, availability, cost of chemicals etc.

(ii) to avoid the toxic effect of chemicals on plants and human beings.

(iii) to maintain a natural balance in agro-eco-system.

iv) to evaluate the performance of these lines and varieties by noticing the degree of infestation.

(v) to identify the sources of resistance for future development of varieties from the view point of acceptable quality and quantity to the farmers.

(vi) to improve the genetic make up of the crop in the process of resistant breeding.

2. Variability studies for different parameters of brinjal for selecting elite types from mixed populations after calculating phenotypic and genotypic variations, heritability and genetic advance for predicting the transmission of characters from the parents to their offspring.
3. Correlation studies among different pairs of characters which may provide information on yield components and thus helps in the selection of superior genotypes from diverse genetic populations.
4. Path analysis of different parameters for getting information on the cause and effect situation between two variables. This analysis permits the examination of various characters on yield as well as their indirect

effects via other components traits. It also provides basis for selection of superior genotypes from the diverse breeding population.

5. $D^2$ statistics measure the forces of differentiation at intra and inter cluster levels and determine the relative contribution of each component trait to the total divergence. The clusters which are separated by the largest statistical distance show maximum divergence. Thus, this technique helps in the selection of genetically divergent parents for their exploitation in hybridization programmes.
6. To protect the crop from the depredation by pests, effect of pesticides were studied to find out the economically and environmentally best pesticides for the resistant varieties selected through screening, following the modern concept of integrated pest management.
7. Exploitation of hybrid vigour obtained from breeding of suitable cultivars with special reference to yield and insect-pest resistance.