

**Population Ecology and Varietal Preference of
Aphis gossypii Glover and *Henosepilachna*
vigintioctopunctata (Fab.) on Brinjal**

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Presented to the
Assam Agricultural University

In partial fulfilment of the requirements for the Degree of
Doctor of Philosophy (Agriculture)
In
Entomology

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CERTIFICATE I

This is to certify that the thesis entitled, "**Population Ecology and Varietal Preference of *Aphis gossypii* Glover and *Henosepilachna vigintioctopunctata* (Fab.) on Brinjal**", submitted to the Faculty of Agriculture, Assam Agricultural University, in partial fulfilment for the Degree of Doctor of Philosophy (Agriculture) in Entomology is a record of research work carried out by **Mr. Kanchan Kumar Shaw** under my personal supervision and guidance.

All help received by him have been duly acknowledged.

No part of this thesis has been reproduced elsewhere for any degree.

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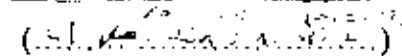
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CERTIFICATE II

This is to certify that the thesis/dissertation entitled, "**Population Ecology and Varietal Preference of *Aphis gossypii* Glover and *Hemosepilachna vigintioctopunctata* (Fab.) on Brinjal**", submitted by **Mr. Kanchan Kumar Shaw**, Regn. No.97-A(D)-3 to Assam Agricultural University in partial fulfilment of the requirements for the Degree of **Doctor of Philosophy (Agriculture)** in the discipline of **Entomology** has been examined and approved by the Students' Advisory Committee and the External Examiner, after viva-voce.

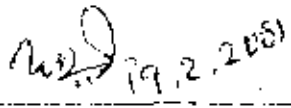


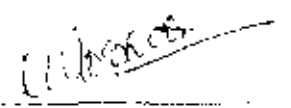
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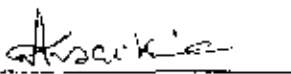


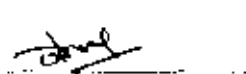
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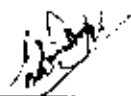
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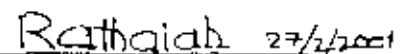
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Jorhat

The Author

ABSTRACT

Investigation on population ecology and varietal preference of *Aphis gossypii* Glover and *Henosepilachna vigintioctopunctata* (Fab.) were carried out on brinjal (winter crop) during 1998 - 99 and 1999 - 2000 at Assam Agricultural University, Jorhat. Both the pests appeared on the brinjal crop at the seedling stage during October - November and remained in the field till maturity of the crop. The population peaks of the aphid and the beetle were recorded during January-February (early reproductive stage) and March (fruit ripening stage), respectively. Three coccinellid predators viz., *Coccinella repanda* Thunb., *Menochilus sexmaculatus* F. and *Micraspis discolor* (F.) were recorded predated on *A. gossypii*. These predators showed significant positive association with the nymphal and adult aphid populations. Bright sunshine hours had significant positive effect on aphid population build-up. Two parasitoids viz., *Tetrastichus* sp. and *Pediobius foveolatus* Craw. were recorded on *H. vigintioctopunctata*. The former parasitized eggs and early instar larvae and the later attacked the later instar larvae and pupae of *H. vigintioctopunctata*. Extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* had significant positive relationship with egg mass and larval and pupal populations of the beetle, respectively. Morning relative humidity exhibited significant negative relationship with the population of the beetle.

The population of *A. gossypii* and *H. vigintioctopunctata* followed negative binomial distribution during both the years. However, distribution became poisson at low population densities during the initial and later phases of infestation. The clumpings of *A. gossypii* nymphs and apterous adult as well as of larvae, pupae and adult of *H. vigintioctopunctata* were, in most of the cases due to environmental heterogeneity and active behaviour of these two pests. Iwao's patchiness regression and Taylor's power law confirmed the results. The optimum sample numbers decreased with the increase of population density.

Studies were carried out on varietal preference of *A. gossypii* and *H. vigintioctopunctata* under field and laboratory conditions. Of the sixteen varieties tested, Aruna and 'Kharua Bengena' were found resistant to aphid infestation, while Pant Samrat, KS-331 and Pusa Bindu were moderately resistant. Higher potassium (K) and moisture content and lower carbohydrate content in the leaves of resistant varieties reduced aphid infestation. 'Kharua Bengena' was the only resistant variety against *H. vigintioctopunctata*, whereas Aruna, KS-331, Pant Samrat, 'Sagalisingia', Muktakeshi and Pusa Kranti were moderately resistant to the attack. These varieties had significantly smaller leaf area, lower red colour intensity of leaves, higher amounts of tannin and phenol, which were responsible for their resistance to the attack of the beetles. No antixenosis factor of the brinjal varieties could be associated with resistance of brinjal varieties against *A. gossypii*. Antibiosis factors in leaves of resistant varieties adversely affected various life parameters of these two pests. The nymphal period and reproductive rate of the aphid and the larval period, pupal period, fecundity, rate of oviposition, adult longevity and sex ratio of the coccinellid were significantly affected by varietal variations.

CHAPTER I

INTRODUCTION

Brinjal is an important and a common vegetable crop grown throughout the world. It usually finds its place as a poor man's crop, because it is a ready source of essential nutrients to poor people besides generating income. As a vegetable, the boiled, fried or stuffed brinjal fruits are real gastronomic delight. It has got much potential as raw material in pickle making and dehydration industries (Singh *et al.*, 1963). Brinjal is very rich in vitamins A, B and C. Purple and green varieties are rich in crude protein and they also contain higher amounts of calcium and iron than the white varieties. The purple varieties are also rich in essential amino acids (Flick *et al.*, 1978). Leaves and fruits of brinjal have some ayurvedic medicinal properties (Nadkarni, 1927). It has been recommended as an excellent remedy for liver complaints, used as appetiser, aphrodisiac, cardiogenic, laxative, murtant and reliever of inflammation. According to Choudhary (1976a), white brinjal is considered good for diabetic patients.

Brinjal (*Solanum melongena* L.) is a solanaceous plant species, grown in tropical and semi-tropical climates throughout the world. It grows well upto an altitude of 1200 m on light soils. It is an annual crop, which requires long warm season (22 – 30^oC) during growth and fruit maturation. Although cultivars differ in their response to temperature variations and can thrive well in winter season also. Brinjal is well adapted to both wet

and dry season cultivation but excessive rainfall checks both vegetative growth and flower formation (Chadha, 1993).

Origin of brinjal is quite confusing. Many workers have mentioned that it is a native of Asia as *S. melongena* have been found growing in India and Burma. Greek and Romans did not know the species and in Europe, it was not known before the beginning of the 17th century (De Condolle, 1904; Vavilov, 1928), while many workers have given contradictory statements. The solid evidence of existence of brinjal crop in India came from 'Amar Kosha', a Sanskrit dictionary of 1100 A.D., where it has been mentioned in several vernacular names. Later on, it has been accepted that the first record of the use of brinjal came from India (Bailey, 1949).

Brinjal is an important commercial crop grown all over India. Presently, it has been widely spread throughout Tropical Asia, Tropical Africa, Tropical America and most tropical and sub-tropical areas (Chadha, 1993). Flick *et al.* (1978) mentioned that purple brinjal variety is widely used but other varieties that differ in colour, size and shape are known. Besides purple, the other colours of brinjal fruit may be white, light green, pink and black.

Brinjal occupies an area of 4,32,000 hectares in the world with the production of 5.54 million tons with an average yield of 146 q/ha (FAO, 1987). In India, it occupies an area of 2,99,770 hectares with the production of 31,24,487 tons (Gill and Tomer, 1991), although Som and Maity (1988) reported that the actual area under brinjal cultivation in India is not possible to estimate because of its seasonal nature of cultivation. International trade is negligible and the crop is consumed more or less locally. This crop is also grown

in great abundance in almost all the districts of Assam and is considered a major remunerative cash crop among vegetables round the year. As per the records (unpublished) maintained during 1998-99 by the Division of Horticulture, Directorate of Agriculture, Assam, the state occupies an area of 15,156 hectares with a total production of 2,30,631 tons per annum.

In India, brinjal crop is infested by nearly 30 different groups of insect and non-insect pests, which include as many as 142 species of insects (Ayyar, 1963; Sohi, 1966; Vevai, 1970; Butani and Verma, 1976; Hill, 1983). Of these, the pests of major importance are shoot and fruit borer (*Leucinodes orbonalis* Guen), stem borer (*Euzophera perticella* Rag), leaf roller (*Eublemma olivacea* Walk), epilachna beetle (*Henosepilachna vigintioctopunctata* F.), aphids [*Aphis gossypii* Glov. and *Myzus persicae* (Sulzer)], jassids [*Amrasca biguttula biguttula* (Ishida)], lace wing bugs (*Urentius* sp.), red spider mite (*Tetranychus* sp.) and root knot nematode [*Meloidogyne incognita* (Chitwood)]. In Assam, cotton aphid *Aphis gossypii* Glover (Homoptera : Aphididae) and epilachna beetle, *Henosepilachna vigintioctopunctata* (F.) (Coleoptera : Coccinellidae) are among the major pests infesting brinjal besides shoot and fruit borer (Borah and Saharia, 1985; Kalita, 1999).

Aphis gossypii Glov. is widely distributed in India, South East Asia, America, Tropical Africa, Europe and Southern Australia (Hill, 1983). It is a polyphagous pest, attacking a wide range of plants belonging to 46 families (Roy and Behura, 1983). They especially feed on cucurbitaceous and leguminous plants. Even though their principal host crop is cotton, they are also considered major pests of brinjal (Butani and Verma,

1976). The nymphs and adults of this aphid are found in large numbers, sucking the cell sap from undersurface of leaves and tender apical shoots. Heavily infested leaves turn yellow, get deformed, curled and dry up causing serious reduction in fruit yield (Agarwala and Raychaudhuri, 1981). In addition, it also secretes 'honey dew', on which fungus (*Capnodium* sp.) develops covering the entire leaf surface and some shoots with black sooty mould, which in turn interferes the photosynthetic activity of the plant and results in poor plant growth and undersized fruits (Butani and Verma, 1976). The aphid makes its appearance in the brinjal field sometimes during the last week of October or early part of November depending upon the climatic conditions and remains active till next April (Roy and Behura, 1983; Kalita, 1999).

Epitachna beetle, *Henasepilachna vigintioctopunctata* (F.) is another common pest of brinjal found all over India. It has a very wide distribution in South East Asia and America. The beetle has 28-spots on the elytra. It is a serious pest of several solanaceous, cucurbitaceous and leguminous crops in Assam (Borah, 1977; Saharia, 1985). The adults and grubs of the phytophagous coccinellid cause damage to the leaves, tender parts and sometimes fruits by scrapping the epidermal layer in a concentric manner. They skeletonize the leaves and in epidemic situations, the crop yield is substantially reduced (Rai and Gopal, 1976). In autumn crop, this pest remains active from November to April or May in Assam (Kalita, 1999).

In Assam, brinjal crop suffers due to heavy infestation of these two pests, more particularly the autumn planted crop, despite the fact that more than 90 per cent of these pests are controlled by the use of modern synthetic organic insecticides. The extremely

rapid rate of multiplication of these pests stands as a big handicap in the effective control measures that might account for the doubtful return for the cost involved in undertaking extra spraying operations. On the other hand, persistent application of insecticide adversely affects the natural enemies and pollinators as well as increased insecticidal residues in plant parts might cause serious health problems arising from the chemical control methods in recent years. This led to greater emphasis on the development and evaluation of resistant varieties. But studies in this regard particularly on aphids and epilachna have not been given due importance till date. However, there are a few reports on use of brinjal as one of the food plants in host preference studies against these two groups of insects (Dutta, 1975; Borah, 1977). There are also preliminary reports from different parts of the country on varietal reactions of brinjal (mostly not recommended for Assam) against aphid (Reddy and Biradar, 1990) and epilachna beetle (Raj and Kumaraswami, 1979; Rajendran and Gopalan, 1998). But such mere reports on reaction of varieties do not provide enough information on the mechanism of resistance.

The success of any pest management programme requires a thorough knowledge of the population ecology including distribution pattern, seasonal history, effect of biotic and abiotic environmental conditions on pest population in different crop stages.

The knowledge of the seasonal trend in population buildup of the pest species and their natural regulation in numbers by the combined effect of biotic and abiotic environmental factors are of paramount importance for proper planning of the pest management strategy. Southwood (1977) pointed out that change of the population fluctuation to a state of stability is associated with an increasing duration of stability in

the biotic and abiotic environments and conversely, the slight changes in these environmental factors would adversely affect the growth of the insect population. Slosser *et al.* (1998) stated that regulation of aphid population densities were governed by abiotic factors and population decline was regulated by abiotic factors while to some workers, the incidence of brinjal aphid is related to relative humidity or sometimes, it is due to cloudiness (Banerjee *et al.*, 1986; Chattopadhyay *et al.*, 1996). Similarly, according to Abbas and Nakamura (1985), the population regulation of epilachna beetle is mostly contributed by parasitism and starvation by overcrowding. In some other reports, it was shown that the density dependant mortality was not caused by starvation and was suggested to be the effect of habitat in stabilizing population numbers (Hirano, 1985). Therefore, it is not conclusively known, actually which factors play significant role in reducing population numbers. The impact of weather and natural enemies as a whole is much more complex and has not been fully understood. Therefore, during the present studies, efforts were made to determine the effects of abiotic and biotic components of the environment individually and in combination on the population of these insects.

The study on distribution pattern of a population is of considerable ecological significance. The spatial distribution pattern adopted by an insect is an intrinsic property of the species (Taylor, 1961). It gives information about the behaviour of the population besides providing a base for developing a sound sampling plan. It determines the method of interpreting population data and can be used for measuring the size of the population (Harcourt, 1961; Taylor, 1984). An understanding of the distribution pattern is also vital

to the analysis of predator-prey and host-parasitoid relationships. Thus adequate information about the distribution pattern of insect population gives an insight to formulate successful pest management strategies. Hence, an effort has been made to understand the spatial distribution of these pests in autumn planted brinjal crop.

The use of resistant variety is a vital component in the integrated pest management system. Selection of genetically variable plant varieties for the resistance to a particular pest, in a particular environmental condition is an important aspect of evaluating and selecting resistant varieties. Incorporation of resistance against one or more insects is desirable to reduce the investment on insecticidal application (Raju *et al.*, 1987). The use of resistant varieties has also got its own advantages as it keeps the plant and its environment unpolluted and therefore it plays a great role in insect pest management programme (Prasad, 1983). Thus an attempt has been made to determine resistance in brinjal varieties against these pests on the basis of their growth and development in laboratory condition as well as their population abundance under field conditions.

Another important aspect that needs greater emphasis is the detection of sources of resistance in promising plant varieties. Resistance mechanism offered by a plant is determined by the combined effects of both bio-physical and bio-chemical status of the plant (Rufener *et al.*, 1987). It is thus necessary to determine and confirm the possible involvement of non-preference or antibiosis factors in conferring resistance to promising varieties against the pest species.

In view of the above facts and paucity in our knowledge on two most important pests of brinjal viz., *Aphis gossypii* Glover and *Henosepilachna vigintioctopunctata* (F.) and realizing the importance of brinjal crop in the North Eastern state of Assam, the investigation was undertaken with the following objectives:

1. to know the seasonal history and population dynamics of *A. gossypii* and *H. vigintioctopunctata* under field conditions,
2. to find out the distribution pattern of *A. gossypii* and *H. vigintioctopunctata* on brinjal in field conditions,
3. to evaluate certain brinjal varieties for resistance/susceptibility to *A. gossypii* and *H. vigintioctopunctata*, and
4. to ascertain possible association of physical (antixenosis based) and biochemical (antibiosis based) plant varietal characters with resistance/susceptibility.

CHAPTER II

REVIEW OF LITERATURE

Brinjal aphid, *Aphis gossypii* Glover is fast becoming a major sucking pest of brinjal in Assam. The severity of damage and losses incurred due to the depredations of this sucking pest of brinjal in Assam, had come to notice in the recent past. Previously, it was a minor pest of vegetables. Likewise, field information on seasonal incidence, reproductive biology, distribution pattern, population dynamics and resistant host plant studies were not available. Therefore, similar works on other or related species from different tropical and sub-tropical areas were reviewed and presented.

The other common and major pest of brinjal, the epilachna beetle, *Henosepilachna vigintioctopunctata* (F.) is a well known pest of solanaceous crop in Assam. It skeletonises leaves and scrap tender apical parts as well as fruits, resulting in substantial yield loss. Despite a few works on its seasonal occurrence, biology and control, all other works relating to the present investigations were from different parts of India and other brinjal growing countries. Moreover, information on spatial distribution pattern of this pest is practically scanty.

2.1. Population dynamics

The general tendency of an insect species to increase in numbers in order to realise its reproductive potential is counter balanced by various environmental factors. In

In Gujarat, the infestation of *A. gossypii* on coriander field commenced from the second week of December and the population increased upto the last week of January, while peak population was observed during January and February (Ghetiya and Butani, 1995) and population of this aphid on cotton peaked (43.05/plant) in the second fortnight of October (Patel and Rote, 1995).

In an experiment on the effect of temperature on seasonal changes of the survival rate of *A. gossypii* population in the warmer region of Japan, Nozato and Abe (1988) found that the survival rates of nymphs and apterous adults of *A. gossypii* in summer on cucumber was low due to high temperature, whereas survival was higher on *Cayratia japonica* leaves due to lower air temperature. In winter, most of the aphids on *Veronica persica* disappeared due to low temperature in the field.

Senapati and Mohanty (1980) reported from Tamil Nadu that the incidence of *A. gossypii* was high in August – October and December – January on cotton, grown in *kharif* and *rabi* seasons, respectively. Cotton plants, 8 – 10 weeks old, succumbed to aphid infestation more than those at other growth stages.

From Orissa, Roy and Behura (1983) reported that the number of alatae, apterae and nymphs of *A. gossypii* per leaf on cotton sown as seed during 1978 – 79 showed highest average population (44.02) during January.

Banerjee and Raychaudhuri (1987), while studying the incidence and reproductive potential of *A. gossypii* on brinjal in the field in West Bengal, found that the population of the aphid peaked on the old, young and tender leaves when the plants were 2, 4, 6 months old, respectively, but the highest incidence was always on the old leaves. There was a

significant positive correlation between nitrogen content and reproductive activity of *A. gossypii* for each of the leaf type.

In another experiment on population fluctuation of *A. gossypii* on brinjal in West Bengal, Banerjee *et al.* (1986) found that the aphid population first appeared in October and peaked in February, when the plants were 5 – 8 months old. The per cent alate viviparous females in the population declined from October till December, then increased again and reached a peak in April. The percentage of apterae increased from November to January. It was also suggested that a relationship existed between the incidence and relative humidity of the environment.

According to Araujo and Sales (1985), population dynamics of cotton aphids, *A. gossypii* on cotton was not affected by minimum, maximum and mean temperatures, relative humidity, direction or velocity of wind, evaporation rate, rain or the number of mature bolls. However, increases in population were favoured by the presence of flower buds and by sunshine.

In Texas, Slosser *et al.* (1998) monitored the abiotic and biotic regulation of *A. gossypii* on cotton. They found that the peak densities of aphids and time of attainment of peak populations were primarily governed by abiotic factors. Average aphid densities were regulated by an interaction of abiotic and biotic factors but rate of aphid population decline was regulated by biotic factors.

Chattopadhyay *et al.* (1996) studied the correlation of sensitivity of *A. gossypii* infestation on cotton to meteorological parameters at Akola, Maharashtra. They found that cloudiness played an important role in the aphid population during the first

generation. When cotton was in elongation stage, a drop in the mean temperature to below 25°C could cause a sharp increase in the aphid population. If there were substantial increases in minimum temperature and relative humidity and an appreciable decrease in sunshine hours with occasional rain, aphid infestation was observed at high levels in these days. Rainfall was found to be the predominant variable controlling the aphid population in the ball formation stage.

Effect of meteorological parameters on aphid population has been demonstrated by several workers in the past (Gutierrez, 1987; Liu, 1986; Debaraj, *et al.*, 1996 on *Aphis craccivora* Koch, *Aphis fabae* Scop. and *Brevicoryne brassicae* L., respectively.

Hirano (1985) studied the population dynamics of a phytophagous lady-beetle *Henosepilachna vigintioctopunctata* (F.) in Japan, that includes 17 patches of host plants. Overwintered adults appeared in potato fields and began to oviposit in May. The first generation adults emerged late in June or early in July, and the potatoes were harvested during this period. The adults then moved to fields of brinjal plants, tomatoes and other crops, but oviposited mainly on brinjal crop. The second generation adults emerged late in July or early August and moved to overwintering sites without oviposition. The higher the adult density, the lower the rate of increase of the number of adult females to the next generation. The number of eggs laid per female apparently decreased as adult density on food plant increased. This density dependence was not caused by starvation. The patchy nature of the farmland habitats seemed to have some effect in stabilizing population numbers.

A study of seasonal abundance of *H. vigintioctopunctata* on some solanaceous host plants in Punjab by Ramzan *et al.* (1990) revealed that the highest number of the pest were found on *Solanum xanthocarpum*, reaching a maximum of 526.3 per ten plants in March.

Peak larval and adult populations of *H. vigintioctopunctata* on brinjal in Tamil Nadu were recorded to be 99 and 226 per 100 leaves, respectively, during January (Raj and Lakshmanan (1980) .

Nakamura *et al.* (1988) studied the seasonal population fluctuation of *H. vigintioctopunctata* on brinjal in Sumatra. They observed that after planting of brinjal crop in the field, adult coccinellids soon colonized and oviposited profusely resulting in rapid population growth for 1 to 2 months, thereafter the population increase was slowed down due to defoliation. Three to 4 months later, the plants came to fresh flushing but leaf quality was less suitable for the coccinellids and as a result, the population remained low during the rest of the period. Adult population size fluctuated 7 to 8 folds during the study period. A life table showed that parasitism and starvation by overcrowding were the key mortality factors for the immature stages.

Takeda *et al.* (1980) studied the seasonal population of *H. vigintioctopunctata* on brinjal in Kakamigahara, Japan. They observed that the overwintered adults of the beetle appeared in early May, adults of the first generation in late June and early July, and those of the second generation in August. Larval population declined towards the end of the second generation.

In Assam, the only report of seasonal occurrence and population dynamics of a phytophagous coccinellid, *Henosepilachna dodecastigma* Wied on soybean was made by Devi (1988). She found that this pest was maximum in their number on May sown crop followed by February and November sown crops. Both temperature and relative humidity exhibited significant positive correlation with the populations in February and May sown crops. Significant positive correlation also existed with rainfall in February and November sown crops and with bright sunshine hours in May sown crop.

In two separate experiments on the population dynamics of *H. vigintioctopunctata* under field conditions and seminatural as well as laboratory conditions in Japan, Nakamura (1976) analysed the key regulatory mechanisms that governed the population density of the pest. In field studies, he found that adults of the first generation emerged in late June or early July. During this period, egg mortality was 27 per cent and was attributable mainly to physiological causes and cannibalism by larvae, while larval mortality was due to starvation. After harvesting of potato, so many adults dispersed to brinjal plant and other solanaceous crops that there was a severe shortage of food resulting in dispersal and reduction in fecundity. Some density dependant mechanisms such as the regulation of fecundity, egg cannibalism, competition for food among the larvae and adult dispersal played an important role in the population dynamics. Nakamura (*loc. cit.*) also found that the number of eggs laid per female in semi-natural condition decreased and the egg cannibalism by adults increased with increasing parental density. During larval stage, mortality was mainly due to food shortage. Thus, the density

dependant regulation mechanisms acting during the adult stage were the key factors governing variations in total survival rates.

Veeravel and Baskaran (1994) reported that interspecific competition between *A. gossypii* and *H. vigintioctopunctata* and intraspecific competition among aphids existed in brinjal ecosystem. They found that aphids were able to eliminate the coccinellids from plants within about 4 to 8 weeks. Significant intraspecific competition within aphid population was seen at densities of 60 and above per plant.

2.2. Natural enemies

Predators, parasitoids and pathogens are important biological agents that play a vital role in the maintenance of delicate ecological balance in their own environment by regulating the prey density in nature. These agents contributes dynamism to the prey population trend.

Venugopal *et al.* (1977) observed three different types of coccinellid predators predated on the natural population of *A. gossypii* on bhendi. These were identified as *Menochilus sexmaculatus* (Fab.), *Coccinella septempunctata* Linn. and *C. repanda* Thunb. Out of these predators, the first one was predominant over the aphid population. There was a positive correlation between predator and prey populations.

Rao *et al.* (1997) studied the biology of two coccinellid predators *viz.*, *M. sexmaculatus* and *Micraspis vincta* on three species of aphids *viz.*, *Aphis craccivora* Koch, *Lipaphis erysimi* (Kltb.) and *A. gossypii* on different crops. They found marked differences in growth and development of predators in different host and food plants.

According to Sugiura and Takeda (1998), *A. craccivora* is the most preferred food for *M. sexmaculatus* (*Cheilomenes sexmaculatus* F.) than *A. gossypii*. In their studies carried out in Japan, they found that the mean development of the predator from hatching to adult eclosion was significantly shorter in *A. craccivora* (18.0 days) than in *A. gossypii* (20.1 to 20.9 days).

In Assam, Saharia (1985) recorded three coccinellid predators of aphids on brinjal. These are *C. repanda*, *C. septempunctata* and *M. sexmaculatus*.

In a study on population ecology of *A. craccivora* on green gram in Assam, Barman (1992) observed six species of coccinellid predators of the aphid, the important ones being *C. repanda* and *Micraspis discolor* (Fab.) with predatory efficiencies of 48.27 per cent and 32.80 per cent, respectively.

From Bangladesh, Haque and Islam (1982) reported that single pair of *M. sexmaculatus* consumed 24.0 to 66.3 numbers of *A. gossypii* per day on chilli.

In Manipur, Devi and Singh (1997) recovered five species of syrphid predators from population of *M. persicae*, *L. erysimi* and *Brevicoryne brassicae* Linn. on knolkhol. Those are *Episyrphus balteatus* DeGaer, *Ischiodon scutellaris* Fabr., *Sphaerophoria indiana* Big., *Metasyrphus confrater* Wied and *Betasyrphus serarius* Weid. A significant positive correlation existed between the population of syrphid predators and *M. persicae*.

Shi (1982) from Shanghai, reported the hymenopterous parasite complex of *A. gossypii* in cotton field. He recorded two peaks of parasitism by aphidiid, one in second half of June and the other between 20th to 30th August. *Binodoxys* (*Trioxys*) *communis* (Gah), *T. rietscheli* Mackauer, *Aphidius gifuensis* Ashm. and *Lipolexis gracilis*

Forst. were primarily found in the field with regular occurrence, while *Aphelinus mali* (Hald.) and *A. abdominalis* (Dalm) were occasionally present.

Dhiman and Kumar (1983) reported the braconiid parasitoid *Diaeretiella rapae* (M'Intosh) on *A. gossypii* in Muzaffarpur, India. The per cent parasitism was 3.44 to 6.66 on brinjal crop.

Palaniswami and Pillai (1980) recovered three species of hymenopteran parasitoids belonging to family Aphelinidae that parasitized *A. gossypii* on taro and tannia. They were *Aphelinus mali* (Hald.), *Coccophagus cowperi* Giv. and *Aphidencyrthus aphidivorus* (Mayr.).

Palaniswami and Pillai (1981) recorded *M. sexmaculatus*, *M. discolor* and *M. vincta* predated aphids on edible aroids, whereas *Stethorus gilvifrons* Muls. was observed to feed both on the mites and aphids. The mean aphid consumption per day by the grub of *M. sexmaculatus* ranged from 15 – 18, while it was 10 – 18 in case of *M. discolor*.

Atakan and Ozgur (1996) studied the fluctuation of natural enemies in the cotton field infested by *A. craccivora* and *A. gossypii* in Turkey. They found that *C. septempunctata* preyed specifically on the aphid, whereas population of *Chrysoperla carnea*, *Aphidoletes aphidimyza* and *Deraecoris pallens* depended on aphid population. Aphid parasitoids *Lysiphlebus fabarum* and *L. confusum* were found in high numbers during preliminary infestation by aphids.

From Meghalaya, Stary and Ghosh (1978) recorded two aphidiid parasitoids viz., *Aphidius colemani* Vier and *Ephedrus plagiator* (Nees) in *Aphis gossypii*.

In Pakistan, *Chrysopa carnea* Stephens larva could consume on an average 487.2 numbers of *A. gossypii* during its developmental stages (Afzal and Khan, 1978).

In Assam, Kalita *et al.* (1996) worked on biocontrol of *A. gossypii* on brinjal by *Beauveria bassiana* (Bals.) Vuill. They recorded 15.91 per cent natural infection of the aphid during the last week of December.

Sheila and Abraham (1981) reported a pentatomid predator, *Cantheconidea furellata* (Wolf.) preying on larvae and pupae of *H. vigintioctopunctata* on egg plant in Kerala. A single nymph or an adult consumed on an average 19 or 16 larvae or pupae per day, respectively.

Saharia (1990) mentioned that praying mantid, *Mantis religiosa* and some banded wasps were predators of many different species of coccinellids.

In a study on population dynamics of *H. vigintioctopunctata* on brinjal in Sumatra, Nakamura *et al.* (1988) recorded two species of *Tetrastichus* parasitizing the eggs and *Pediobius foveolatus* Craw, parasitizing the pupae. Four species of coccinellids were also reported as possible predators of the beetle.

Rajendran and Gopalan (1997) examined the potentiality of the eulophid parasite, *P. foveolatus* on the grubs of *H. vigintioctopunctata* in brinjal crop. They recorded maximum parasitization of 49.5 per cent in August, 49.1 per cent in November and 47.1 per cent in September.

According to Raghuraman and Vecravel (1999), the average time for development of *P. foveolatus* from egg to adult was 10 to 16.5 days on

H. vigintioctopunctata infesting brinjal under laboratory condition, with 11.0 to 22.6 parasitoids emerging per host.

Abbas and Nakamura (1985) studied the life table of an epilachna beetle feeding on bitter cucumber in Sumatra. The study indicated that egg mortality of the beetle to the tune of 41.1 to 64.2 per cent was attributed to *Tetrastichus* sp. Another species of *Tetrastichus* along with *P. foveolatus* killed 1.2 to 19.4 per cent of 4th instar larvae, and *P. foveolatus* alone killed upto 59.1 per cent of pupae.

Toquebaye and Marchand (1984) recorded the presence of a naturally occurring microsporidiosis in the cucurbit coccinellid, *Henosepilachna elaterii* (Rossi) in Africa. It was *Nosema henosepilachnae* found in eggs, larvae and adults, but it did not kill the host immediately.

Beevi and Jacob (1982) studied the relative susceptibility of stages of *H. vigintioctopunctata* to infection by *Fusarium moniliformae* var. *subglutinans*. They found that third and fourth instar larvae were more susceptible to the fungus suffering 100 per cent mortality after 5 days of inoculation. The mortality of first and second instar were 96.7 per cent and 90.7 per cent, respectively, while pupae exhibited 80.0 per cent and adult 76.7 per cent mortality.

2.3. Distribution pattern

The study of distribution pattern is a pre-requisite for understanding the population behaviour of a species. According to Taylor (1961), the spatial distribution pattern adopted by an insect is an intrinsic property of the species and an important aspect of its structure. The distribution behaviour of an insect affects the precision of sampling,

method of analysing data and investigations on the dynamics of pest populations when changes in size are considered. Study of distribution pattern is therefore used to measure population size and description of the condition of population (Southwood, 1978). An adequate knowledge of distribution further justifies the statistical analysis for suitable transformation of data to stabilize variances and to develop sound sampling plans needed for formulating successful pest management strategies.

Denechere (1981) observed the distribution of *A. gossypii* on cotton plant, the relationship between the per cent of plants or leaves infested and the actual counted population, and the variability of aphid numbers from plant to plant, led to the conclusion that sampling can be limited to the 6 upper leaves although aphid is found mainly on the lower part of the plant. He found that the population of *A. gossypii* had an aggregated distribution that could be determined by a negative binomial law and also determined the size of the sample (number of plants) as a function of the mean.

Trumble *et al.* (1983) reported that spatial distribution of *A. gossypii* infesting winter strawberries in coastal California were initially overdispersed but became random as population increased, as indicated by results of Green's (1966) coefficient C_x and patchiness index. Distribution remains random after population collapse, suggesting that density-independent factors suppressed them. Iwao's regression gave similar results when populations were temporarily stratified.

The spatial distribution of egg masses and larvae of the coccinellid, *H. vigintioctopunctata* was studied on brinjal from February, 1979 to December, 1980 by Suman *et al.* (1987). They found that egg masses were distributed randomly with a

tendency towards aggregation at high densities. The larval and pupal population had aggregated distribution. A good fit to the binomial distribution was obtained from the larvae and pupae.

Edelson (1986) studied the distribution pattern of different insect pests including *A. gossypii* on cantaloupe in Texas. He found that aphids were most abundant on basal part of vines. He also evaluated sampling techniques for each species using relative variation and suggested that precision could be increased by reducing the area sampled and increasing the number of samples.

Singh *et al.* (1990) reported that the spatial distribution of *A. gossypii* was aggregated at the end of the season in apterous aphids on upland cotton in Punjab during July to September. Environmental heterogeneity at low population in July, and innate behaviour at high population were responsible for the aggregated dispersion of the species.

Nath and Nag (1996) studied the spatial distribution pattern of the aphid, *A. craccivora* Koch on french bean cultivars, viz., HUR-15 and VL-63 in Varanasi. They found that the variance/mean ratio was lesser than unity indicating regular pattern of aphid population distribution. The binomial model did not confirm this but the three approaches for generalised system of frequency curve showed that the aphid population was regularly distributed in both the cultivars of french bean.

Barman and Dutta (1997) from Assam reported that the alatae and apterae of *Aphis craccivora* Koch dispersed in a regular pattern in green gram crop. These two adult forms of the aphid showed a tendency of clumping at higher population densities. Mean

clump size indicated that environmental heterogeneity in the crop habitat and active **behaviour** of the apterae were the causes of clumping.

Zhang *et al.* (1998) developed the binomial count analysis based on the spatial **distribution** and population density estimation of *A. gossypii* on cotton seedlings in China **during** 1991. Data consisting of 24 estimates of mean aphid density (m), variance (s^2) and **the** proportion of plants (P_T) with no more than T aphids was obtained. Taylor's power **law** fitted the data well ($r^2 = 0.958$) with the resulting slope (1.515) significantly greater **than** 1, which indicated that spatial distribution of the aphid was aggregated. Small T **values**, particularly aphid free plants, could lead to spurious estimates of m from P_T . A value of T from 10 to 15 was recommended to develop binomial sampling plans for **aphids** on cotton seedlings because of relatively small sampling errors.

ADU-Gyamfi and Morimoto (1997) studied the effect of spatial distribution on **mortality** of the immatures and associated predators of the epilachna beetle, *H. vigintioctopunctata*. They found that the mortality of the beetle was higher in the **uniform** distribution than with the clumped one. This mortality was because of the **dominant** predators. Since predation was the major mortality factor, and this was **contingent** on prey distribution, predation probably acted with varying intensities in the **plots** supporting the two different spatial distribution patterns.

Burgio *et al.* (1994) observed that the spatial distribution pattern of *A. gossypii* on **tunnel** grown cucumber and melon in Italy, showed aggregate pattern distribution of the **aphid** and to the rapid development of infestation in the field. The aggregation index was **not** significantly different between years of study or sites and between crops.

In Columbia, spatial distribution pattern of *A. gossypii* on cotton was aggregated. This spatial distribution was interacted by natural enemies (Vergara and Galeano, 1994).

2.4. Plant resistance

Resistance of a plant to insects as defined by Painter (1951) is the “relative amount of heritable qualities possessed by the plant which influences the ultimate degree of damage done by the insect”. He stated that the inherent qualities were specific to the variety, which imply existence of a resistance mechanism in the plant. He recognized three inter-related bases or mechanisms of the phenomena of resistance, viz., non-preference (antixenosis), antibiosis and tolerance. One or more of which is frequently operating in resistant varieties. A perusal of relevant literature reveals that the plant varieties exhibited varying degree of resistance or susceptibility to the insect attack. Plant resistance is the most economical and ecologically safe method of pest management. It avoids all hazards associated with the chemical control measures.

2.4.1. Resistance based on the population pressure and plant injury

Ganga and Nagappan (1983) reported the monthly feeding budgets of *H. vigintioctopunctata* on two cultivated and two wild solanaceous plants. Rates of feeding and assimilation by the beetle on *Solanum melongena* L. are the highest, followed by *Datura fastuosa* L., *Lycopersicon esculentum* Mill. and *Physalis minima* L., whereas highest conversion rate was achieved by feeding on *P. minima*.

Mote (1978) screened 48 brinjal varieties for their resistance to jassid, *Amrasca biguttula* Ishida under field conditions. On the basis of insect population, H-4, Round Green, Dorly, Aushey, Long Purple, Pusa Purple Round, A-61, Jumblimulayam, White

Green, Manjurigota, Round White, Black Beauty, Round Purple, American Black Beauty, B-14 and Banaras Giant showed less number of jassid nymphs as compared to others; whereas White Kalyanpur T₂, Round Green, Round Purple, Long Purple, White Green, American Black Beauty, Banaras Giant, Jumblimulayam and BR-114 had least jassid injury.

Raj and Kumaraswami (1979) screened 41 varieties of brinjal at Madurai to locate resistance to *H. vigintioctopunctata* based on visual feeding score. Among the varieties, minimum damage to the leaf was noticed in Arkashirish, which was *at par* with seventeen other varieties. This variety was closely followed by Hissar Selection 1-4, Shankar Vijay, Pusa Kranti, Pusa Purple Cluster and Arka Navneeth. The maximum leaf damage was recorded on the variety, Punjab Chemkib. Pusa Purple Round, Pusa Purple Long, BR-112, S.M. 311 and A-61 are also highly susceptible to the attack of this beetle.

Sambandam *et al.* (1974, 1976) tested 114 brinjal varieties including wild *Solanum* spp. for resistance to *H. vigintioctopunctata*. Out of which, Apple Green Flesh and Pusa Purple Round were found to be moderately resistant and *S. torum* was highly resistant to feeding of this beetle.

In Assam, Isahaque and Chaudhuri (1984) tested ten varieties of brinjal for resistance to shoot and fruit borer, *Leucinodes orbonalis* Guen. They found that 'Bhola Bengena' was the most susceptible and 'Kuchia' was the least susceptible to the borer. Other less susceptible varieties which was *at par* with the variety 'Kuchia' are "Nal Bengena", Pusa Purple Cluster and "Chagolisingia".

Reddy and Biradar (1990) evaluated six varieties of brinjal viz., MDU₁, Erengere, CO₁, Annamalai, Panruti Local and Kengeri for their relative resistance to the aphid, *A. gossypii* under pot culture conditions. Aphid population build-up assessed at weekly intervals indicated that amongst the six varieties screened, Panruti Local was the most resistant (av. 10.16 aphids/leaf in 1986-87 and 8.60 aphids/leaf in 1987) and Erengere was found to be the most susceptible (69.24 and 65.88) followed by MDU₁ (47.09 and 49.45), Kengeri (31.02 and 31.14), Annamalai (20.18 and 19.80) and CO₁ (13.65 and 14.79).

Jyani *et al.* (1995) screened brinjal varieties for their resistance to different insect pests and diseases. Varieties such as Chaklasi Doli, Doli-5 and Pusa Purple Cluster showed resistance to some extent. But none of the varieties showed resistance to *A. gossypii*.

Prasad (1983) identified resistance in plants, viz., yellow sarson (29 cultivars), brown sarson (30 cultivars) and rai (40 cultivars) against mustard aphid, *Lipaphis erysimi* (Kalt.) by comparing mean aphid infestation index. Yellow sarson cultivar, IB-417 and brown sarson cultivar, T-22 were less susceptible, while rai cultivar, IB-680 was least susceptible to aphid infestation.

The relative performance of 83 *Brassica* germplasms against mustard aphid, *Lipaphis erysimi* (Kalt.) infestation was screened based on aphid infestation index (0 – 5 rating scale). The screening revealed that two germplasms, viz., B-85 glossy and RW-White Glossy were graded as highly resistant, 13 germplasms as resistant and 21 as

moderately resistant; whereas 42 were susceptible and 5 germplasms as highly susceptible (Lal *et al.*, 1997).

Rajendran and Gopalan (1997) screened 78 accessions of *S. melongena*, 15 hybrids and 10 wild *Solanum* spp. based on comparison of damage index of leaves fed by *H. vigintioctopunctata*. Amongst the hybrids, EP 24 x 65 alone was moderately resistant. All the wild accessions were resistant except *S. macrocarpum* (BE-046/EP154), which was moderately resistant. Among the 78 cultivable accessions screened, none was resistant, but 15 accessions were moderately resistant to spotted beetle.

In another experiment, Rajendran and Gopalan (1998) screened 103 brinjal cultivars against *H. vigintioctopunctata*, out of which 9 entries were graded as resistant, 17 as moderately resistant and 77 as susceptible based on damage index, that involved only intensity of leaf damage under cage studies in the field. Among the hybrids, EP24 x 65 alone was moderately resistant and others were susceptible. All the wild accessions were resistant except *S. macrocarpum*, which was moderately resistant. The mean percentage of leaves affected in the moderately resistant entries varied from 22.5 – 42.5. Similarly, the mean leaf area damaged in 24 hour under caged studies ranged from 0.52 – 0.68 cm².

2.4.2. Resistance based on comparative biology and ethology

Open field screening often does not permit identification of individual resistant plants in segregating plant populations because plants are usually rated on a plot basis. A laboratory non-preference method therefore, often deployed or suggested as a bioassay that would complement field screening methods (Kogan, 1972). In this regard, relevant

literature pertaining to laboratory screening of the concerned species or closely related species were reviewed for drawing conclusions.

Phukon (1976) studied the effect of different solanaceous host plants viz., potato, night shade and brinjal on the development of *H. vigintioctopunctata* in Assam. He found that larval and pupal duration lasted longer on brinjal i.e., 21.00 days and 5.93 days, respectively, while night shade was the most favoured food, where larval duration (14.95 days) and pupal duration (4.84 days) was shortest. Adult lived 36.6 days on brinjal and 60.6 days on night shade was the longest. Fecundity was more in beetles fed on night shade (326.0 egg) and least on brinjal (134.66 eggs).

Borah (1977) studied the effect of food plants on larval and post larval development of *H. vigintioctopunctata* in 10 different cucurbitaceous crops in Assam. He recorded that grubs and adults preferred leaves of sweet gourd (*Momordica cochinchinensis* Spreng) and it was the most preferred host as indicated by short larval duration (12.7 days) and shorter development period (21.28 days), while cucumber was the most unfavoured food with a larval duration of 19.5 days and total developmental period, 29.48 days. The leaf area consumption per grub or adult per 48 hours by a single choice host tests measured 26.24 sq. cm and 27.55 sq. cm on sweet gourd, respectively, was the maximum. However, the leaf area consumption of the beetle according to Imura and Ninomiya (1998) on a weed *Solanum carolinense* was 1429.5 mm², consumed by a larva during its entire developmental period and 2510.9 mm² by an adult during first 10 days of its emergence. Whereas Phukan (1976) recorded leaf area consumption by a grub and an adult of the beetle to be 6.69 sq. cm and 6.25 sq. cm per day, respectively.

Microscopic examination of stylets and sheaths and probing behaviour of the melon aphid, *A. gossypii* on resistant and susceptible musk melon, *Cucumis melo* L. revealed pronounced differences in probing on the two lines. Relative to the susceptible line, 'Top Mark', stylets and sheaths in the resistant line 91213, had significantly more branches ending in the phloem. Aphid probing revealed that on the resistant plants, a significantly greater percentage of the probes led to the stylet contact with the phloem sieve cells, but a smaller proportion of the sieve cell contacts resulted in ingestion than was the case on susceptible plants. In addition, the duration of periods of ingestion from the sieve cells was greater on susceptible than on resistant plants (Kennedy *et al.*, 1978).

Kennedy and Kishaba (1977) conducted a series of experiments to characterise responses of alate *A. gossypii* to resistant and susceptible musk melon, *C. melo* plants. There was no effect on survival and reproduction of aphids, which were confined for 16 hours on resistant plants and transferred to susceptible plants. When given a choice, 51 per cent of uncaged aphids remained on the resistant plants as compared to 83 per cent on the susceptible plants, indicating the resistant plants exerted at least a moderate arrestant effect on the aphids. The weaker arrestant effect of resistant than susceptible plants resulted in greater inter-plant movement of aphids on the former.

In a study on feeding behaviour of *H. vigintioctopunctata* in *Luffa aegyptiaca* Mill., Sinha *et al.* (1977) observed that larvae are attracted mainly to the flowers in the light, as are the adults of this species. In the dark, however, unlike the adults, the larvae preferred the leaves, flowers and fruits and this behavioural differences presumably reflects differences in the nature and function of certain attractants and arrestants

contained in these parts of the plant. For feeding, the larvae show a preference for the fruits, which again distinguishes them from the adults.

Sachan and Rathore (1979) evaluated the developmental potential of *H. vigintioctopunctata* on 6 wild solanaceous plants viz., *Solanum pubescens*, *S. xanthocarpum*, *S. indicum*, *S. melongena*, *S. khasianum* and *Datura fastuosa*. On all the plant tested, larvae failed to develop on *S. pubescens* only. The average life span was greatest on *S. xanthocarpum* and shortest on *S. khasianum* but died within a few days of emergence without laying any eggs. The preoviposition, oviposition and post oviposition periods also varied and were longest on *S. xanthocarpum* and shortest on *S. indicum*. Fecundity was also highest on *S. xanthocarpum* but lowest on *D. fastuosa*. More number of males than females emerged on *S. khasianum*, while on *S. melongena*, females outnumbered males, but according to Al-Iraqi and Farag (1986), the sex ratio was about 1:1 on squash.

According to Vasantha *et al.* (1986), the preference of third and fourth instar larvae of *H. vigintioctopunctata* on the leaves of solanaceous plants was studied in the laboratory. Brinjal was the preferred food plant followed by tomato, *Datura fastousa*, *Physalis minima* and *S. nigrum*. Continuous feeding was not observed in *S. torvum*. Assimilation efficiency was generally greater than 95 per cent on all the preferred food plants. Third instar larvae, which were of small size and often died before reaching the 4th instar.

In a larval antibiosis screening test conducted on 14 soybean varieties against Mexican bean beetle, *Epilachna varivestis* Mul., Rufener *et al.* (1987) found that larvae

developing on susceptible lines like Beeson, Sprite and Williams were visually larger, more active, had consumed larger amounts of leaf materials, had faster rate of development and low mortality rates than larvae exposed to the more resistant lines, such as L76-0272, L76-0038, L-78-608 etc.

Ramzan *et al.* (1990) reported that *H. vigintioctopunctata* completed its life-cycle more quickly on *Solanum nigrum* (22.4 days) as compared to other solanaceous host plants tested, although field population was highest on *S. xanthocarpum* at the same time during March.

Ekukote (1990) tested the effects of host plants, viz., okra, cotton, melon, groundnut on the fecundity of *A. gossypii* in laboratory at 25°C, LD 12:12 and 55 per cent relative humidity. He found that fecundity was higher on okra and cotton, which registered 5.16 and 4.76 nymphs per aphid per day, respectively.

Foicía *et al.* (1996) studied the comparative development of *H. vigintioctopunctata* on brinjal, *Solanum bonariense* and tomato in laboratory at 25°C. According to him, brinjal was the most preferred food, where larval and pupal stages lasted 24.4 ± 4.52 days and 4.7 ± 0.826 days, respectively.

Klingler *et al.* (1998) studied the effect of resistant musk melon, *Cucumis melo* line AR-5 on feeding behaviour and performance of *A. gossypii*. He showed that resistance is expressed within the plant rather than on its surface, because the time to first stylet penetration was not significantly different between AR-5 and closely related susceptible breeding lines PMR-5. Significant behavioural differences were observed only after stylets contacted phloem sieve elements. On AR-5, duration of salivation after

sieve element puncture was significantly longer, and the number of aphids showing phloem sap ingestion was significantly reduced. Monitoring of two genotypes showed that aphid feeding was delayed and greatly reduced on the resistant genotype. Comparison of aphids life history, population development between host plant genotypes showed that the effects of resistance acted throughout aphid development and highly effective in slowing down population increase.

2.5. Resistance mechanism

Insects are noticeably reluctant to colonize on some individual plants or on some particular strain of host plant and these plants seem to be less attractive to the pest by virtue of their texture, colour, odour or taste. This mechanisms of resistance offered by such plants includes an array of physical and chemical characteristics that interferes with locomotion, feeding, ingestion, mating and oviposition of insects (Norris and Kogan, 1980). Physical or non-preference based mechanism usually is revealed when the insect refuses to feed, refrains from laying eggs, or less acceptable to plant colours etc. These resistance are generally characterized by anatomical features such as thick cuticle, hairy leaves or stems, plant height, age of the leaf, etc. On the other hand, biochemical aspects usually involve the presence of various toxic or distasteful chemicals in the sap of the tissue of the plant, which effectively repel feeding or, sometimes to the extent that the odour is sufficient to completely deter insects from feeding.

Details of plant resistance mechanism in brinjal crop against *A. gossypii* and *H. vigintioctopunctata* are not sufficiently available in the available literature. Therefore,

some related works in this field involving different plant and insect species were also reviewed.

2.5.1. Non-preference based resistance mechanism

Painter (1951) speculated that cell wall thickness of epidermis of cotton leaves might be of importance in imparting resistance to insect attack.

Hill (1983) reported that solanaceous plants often have peculiar glandular hairs on the leaves and stems that exudes sticky substances which easily trap small insects like aphids and even large insects like larvae of Colorado beetle. He also reported that hairy leaved varieties of wheat in North America was attacked significantly less often by the cereal leaf beetle, *Oulema melanopus*. The female laid fewer eggs on the leaves and of the larvae that hatched, fewer survived. Similarly, high density of these hairs on brinjal leaf also supported fewer leaf hoppers *Amrasca biguttula biguttula* (Schreiner, 1990).

Certain aphids with shorter stylets are known to be prevented from feeding by the thick parenchymatous layers covering vascular bundles (Gibson, 1972). Thick cortex of wild tomato relative *Lycopersicon hirsutum*, on the other hand, prevented the potato aphid, *Macrosiphum euphorbiae* Thomas from reaching the vascular tissues (Quiras *et al.*, 1977).

Kale *et al.* (1986) showed the varietal resistance of 32 cultivated varieties of *Solanum melongena* and 4 wild types viz., *S. incanum*, *S. xanthocarpum*, *S. khasianum* and *S. sisymbriifolium* against brinjal shoot and fruit borer, *Leucinodes orbonalis* Guen. It revealed that the immunity of wild types and highly resistant cultivars of the other varieties were attributed to dense pubescence with long, tuft and erect trichomes.

Phukan (1976) studied resistance of brinjal plants in comparison with other solanaceous host plants, viz., potato and night shade against *H. vigintioctopunctata*. Resistance was believed to be associated with higher leaf pilosity of 67.70 per 9 sq. mm in brinjal against 4.90 and 39.6 in potato and night shade, respectively.

According to Levin (1973), the density and length of trichome branches in some plants were negatively correlated with insect survival.

Reddy *et al.* (1986) reported that hairiness on the ventral surface of leaf coupled with leaf thickness is responsible for imparting resistance against whitefly (*Bemisia tabaci* G.).

Gilbert (1971) reported that hooked trichomes on leaves trapped small insects and the insects died of starvation and dessication.

Dariev *et al.* (1979) found that the less infestation of *A. gossypii* on cotton was due to leaves which had large numbers of glandules, hairs and mesophyll cells. Cotton leaves with 100 hairs per sq. mm completely prevented movements of insects. Wang (1983) also suggested that these aphids show non-preference on pubescent cotton variety Kang-77, which was attributed to the marked pubescence of the leaves.

According to Negm *et al.* (1980), the leaf hair density played a minor role in limiting the aphid population, which conceded 5.8 per cent reduction in population of *Aphis craccivora* Koch on cowpea.

Pierce (1983) reported that some lines of lucerne having erect and glandular hairs on the stem that fights off pests such as spider mites, aphids and alfalfa seed chalcids.

In a study on varietal susceptibility of ten brinjal varieties to jassid, *Amrasca biguttula biguttula* Ishida, Mote (1982) identified mechanisms of resistance being density and length of leaf hairs observed on varieties viz., Muktakeshi (48.0 per sq. mm and 0.097 mm), Round Green (53.0 per sq. mm and 0.090 mm) and Kalyanpur T₃ (57.0 per sq. mm and 0.096 mm). The number of eggs laid was larger on varieties such as Pusa Kranti, Pusa Purple Long, Kalyanpur T₂ and Black Beauty with leaf hair density 32.0, 30.0, 27.0 and 29.0 per sq. mm, respectively.

In a field study, Isahaque and Chaudhuri (1984) evaluated comparative susceptibility of 10 varieties of brinjal plants to shoot and fruit borer, *L. orbonalis* in Assam. They showed that local variety 'Bhola Bengena' to be the most susceptible and 'Kuchia', another local variety to be the least susceptible to the pest. Varieties having round, oblong and oval fruits, broad leaves, thinly placed hairs on top internodes, less lignified, less compact hypodermal sclerenchyma with narrow and less compact vascular bundles were found to be more susceptible.

In Uganda, Stride (1969) showed that cotton lygus bugs, *Taylorilygus vosseleri* Popp. was less responsive to some red coloured varieties of cotton for feeding rather than the usual green plants.

Herrera and Muniz (1979) studied the responses of *Epilachna varivestis* Muls. to coloured surfaces in the laboratory. Coloured cards offered to the overwintering generation adult beetles preferred black over all other tones and colours. The second choice was red, followed by yellow, coffee, green, blue, grey and white in the order, while the third choice was yellow, followed by coffee, grey, green, blue and white. In

tests with the post-overwintering generation (the first generation), black was again the most preferred followed by red. Preliminary field studies indicated that adults were attracted to yellow and white.

Pathak (1961) reported that the colour of the leaf might be a possible factor or index for aphid resistance. He observed that light pale coloured leaves of *Brassica campestris* were more susceptible to the aphid attack than the varieties with dark coloured leaves.

Ilse (1937) showed that *Pieris brassicae* (Linn) butterflies were attracted to green and blue green substrates where they could display a pre-ovipositional behaviour. Yellow substrate did not release such behaviour.

Devi (1991) observed that light green coloured leaves of cabbage and cauliflower harboured higher larval population of *Pieris canidia*.

2.5.2. Antibiosis based resistance mechanism

McGarr (1942) indicated that increased level of nitrogen accounted for susceptibility of cotton to cotton aphid, *A. gossypii*.

It is thought that in some resistant plants, the pest suffers nutritional deficiencies, resulting from the absence of certain essential amino acids (Hill, 1983). According to Davis (1972), for proper protein nutrition, insects require the common 10 amino acids although quantitative requirement may vary to some degree.

Edward and Wratten (1980) stated that reduced water supply acts indirectly on insects by changing the nitrogen balance in plants.

Shvetsova and Alibekova (1984) studied the effect of the protein complex of cotton on the activity of digestive enzymes of the cotton aphid, *A. gossypii* in USSR. They showed that protein heterogeneity, proteinase activity and the crude protein content could be used as one of the criteria for determining the resistance of cotton varieties to sucking pests.

According to Banerjee and Raychaudhuri (1987), brinjal leaves of varied maturity showed remarkable variations in respect to the retention of nutrient contents therein. The contents also varied along with the increase of plant age. Amongst the nutrient content of the leaves, nitrogen level showed a significant positive correlation with the reproductive potential of *A. gossypii* leading to the population outbreak.

Ganga and Nagappan (1983) presented the monthly feeding budgets of *H. vigintioctopunctata* on two wild and a few cultivated solanaceous plants. Rates of feeding, assimilation and conversion by the beetle on brinjal are 1.789, 1.1661 and 0.0185 mg/day/g fresh weight, on *Lycopersicon esculentum* 0.3205, 0.3125 and 0.0199 mg/day/g fresh weight, on *Datura fastuosa* 0.8746, 0.8659 and 0.0217 mg/day/g fresh weight and on *Physalis minima*, 0.2378, 0.2326 and 0.0481 mg/day/g fresh weight, respectively. The assimilation efficiency was above 98 per cent on all the four plants. The highest rate of feeding and assimilation by the beetle on brinjal was due to higher content of protein. There was a positive correlation between protein content of leaf with ingestion and assimilation.

Panda and Das (1975) investigated the preferential antibiosis in shoots and fruits of resistant and susceptible brinjal varieties and its adverse effects on various phases of

life history of *Leucinodes orbonalis* Guen. The survival of larvae, growth index and pupal period were significantly less in resistant varieties than in susceptible ones. The sex ratio and fecundity of moths were also significantly reduced in resistant varieties. Among the chemicals, higher silica and crude fibre in the shoots of resistant varieties helped to check the borer damage. The susceptible brinjal varieties had high total sugar content and two essential amino acids. The sugar and amino acids acted as feeding stimulants in susceptible varieties.

From a study to evaluate mechanism of resistance in egg plants and certain wild *Solanum* species to *H. vigintioctopunctata*, Sambandam *et al.* (1976) concluded that preferential feeding and antibiosis were the main factors affecting resistance. They found that susceptible accessions had the highest total of amino nitrogen, amino acids, starch, crude fibre and potassium contents, whereas the moderately or highly resistant accessions had the higher reducing and non-reducing sugars, chlorophyll, phosphorus and total phenol contents.

Flick *et al.* (1978) examined and compared the biochemical compositions of purple, green and white varieties of egg plant as a nutritionally favoured food while egg plants contained the greatest amount of solids and green the lowest. Crude protein was only slightly higher in purple and green egg plants than in white but both the green and white varieties contained more ash than did the purple. Crude fibre content was similar in both the purple and green egg plants, whereas the white variety contained almost twice as much. Among the trace elements, potassium was highest in the green and lowest in the purple variety. The amount of all amino acids was higher in purple egg plants than in the

other varieties. Finally, it was suggested that purple egg plant varieties were the most favoured food from the nutritional point of view.

Phukan (1976) studied the effect of host plants *viz.*, potato, night shade and brinjal on the development of *H. vigintioctopunctata* under laboratory condition in Assam. He found that night shade was the most susceptible host followed by potato. The susceptible host had higher crude protein (24.6 – 25.8 per cent) and lower total soluble sugars (0.7 – 1.5 per cent) than the less susceptible brinjal cultivars, which had 18.6 and 1.70 per cent crude protein and total soluble sugar, respectively.

Negm *et al.* (1980) opined the total carbohydrate and soluble sugars were the key factors limiting the *A. craccivora* population on cowpea as it affected 68.99 per cent of the population changes. They expressed that amino acids played a minor role as it brought about a mere 5.8 per cent of the changes. Only total carbohydrate, soluble sugars and Ca^{++} played significant roles in aphids mortality.

In Assam, studies by Isahaque and Chaudhuri (1984) on comparative susceptibility of ten varieties of egg plants to shoot and fruit borer, *L. orbonalis* revealed that the high amount of sugars and proteins were more susceptible. Local variety 'Bhola Bengena' was the most susceptible which had 4.27 per cent crude protein and 5.62 per cent total sugars, while another local variety 'Kuchia' was adjudged least susceptible to the borer, which has 3.00 and 3.04 per cent crude protein and total sugars, respectively.

Kale *et al.* (1986) screened out 32 cultivated varieties and four wild types of brinjal for their resistance to shoot and fruit borer, *L. orbonalis*. They found all wild types to be immune, eight and three cultivars to be highly resistant on the basis of shoot

infestation and fruit infestation, respectively. Biochemical compositions in relation to resistance revealed that moisture, crude protein and ascorbic acid contents of the shoot were not associated with the resistance, whereas, immune wild types and highly resistant varieties had a combination of high silica and high crude fibre contents and comparatively less ash and crude fat contents in the shoots than others.

Of the eight varieties of egg plant screened for resistance to *H. vigintioctopunctata*, 'Punjab chenakate', SM-204 and SM-195 showed moderate resistance to the beetle. Low nitrogen (3.26 – 3.93 per cent) and potash (0.91 – 1.03 per cent) and high amounts of phosphorus (0.41 – 0.48 per cent), total carbohydrates (14.23 – 15.56 per cent) and phenols (0.40 – 0.44 per cent) of the host leaves were implicated with the moderate resistance of varieties to the epilachna beetle (Raju *et al.*, 1987).

The role of tannins in imparting plant resistance to insect was described by Ishaaya (1986). He also stated that growth inhibition in insects by these compounds are probably due to complex interactions that include a lowered food intake, decreased activity of midgut enzymes and a reduced level of proteins and sugars in the haemolymph.

Borah (1987) showed that tannin in chilli played an important role resistant to *Polyphagotarsonemus latus* (Banks) and *Scirtothrips dorsalis* Hood. The study indicated that, the damage caused by the thrips and the mites were inversely proportional to the total tannin content of the plant.

MATERIALS AND METHODS

The studies on population ecology and varietal preference of *Aphis gossypii* Glover and *Henosepilachna vigintioctopunctata* (Fab.) were carried out during 1998-99 and 1999-2000. The field experiments were conducted at the experimental field of the Department of Entomology, Assam Agricultural University, Jorhat, situated 26^o47' N latitude and 94^o12' E longitude and at an altitude of 86.80 meters above mean sea level. The laboratory investigations were carried out in the Department of Entomology, Assam Agricultural University, Jorhat.

All the experiments related to population ecology were carried out on brinjal variety "Pusa Purple Long" (recommended for Assam) and those related to varietal preference were carried out on 16 cultivated brinjal varieties. The studies were carried on winter crop which takes about 220-250 days to mature.

The materials and methods followed in different experiments are presented hereunder.

3.1. Seasonal history and population dynamics of *A. gossypii* and *H. vigintioctopunctata*

Seasonal population trends and population dynamics of *A. gossypii* and *H. vigintioctopunctata* were studied on brinjal variety, Pusa Purple Long, in the experimental field of Assam Agricultural University, Jorhat. The crop was grown in an area of 450 sq. m consisting of three plots measuring 150 sq. m (15 m x 10 m) and separated from each other by 1 m gap between plots. The seeds were sown (3 September, 1998 and 28 September, 1999) in a well prepared nursery bed (2m x 1m) provided with temporary poly shade at the top. The seedling were transplanted (7 October, 1998 and 4 November, 1999) in different plots with a row to row spacing of 75 cm and a plant to plant spacing of 60 cm. The crop was raised following the recommended package of practices (Anon, 1997) except plant protection measures so as to encourage population buildup of both the pests and their natural enemies without intervention.

3.1.1 Sampling procedure

Plant inspection method was used for sampling *A. gossypii* and *H. vigintioctopunctata* populations during the entire crop season.

For sampling *A. gossypii*, 15 plants were randomly selected from 3 plots (5 from each plot). During the early crop growth stage (upto 5 leaf stage) the adults and the nymphs were counted from all the leaves of the selected plants. During the latter stages of the plant growth, the population was drawn from 6 leaves (2 from top, 2 from middle and 2 from bottom canopy) per plant.

For sampling of *H. vigintioctopunctata*, 30 randomly selected plants were taken from 3 plots (10 plants per plot). At the early stages of the crop the adult, larval and the pupal populations as well as number of infested leaves were recorded per plant sampled. During the latter stages of the crop, these records were taken from two branches of each plant selected.

For both *A. gossypii* and *H. vigintioctopunctata*, samples were taken at weekly intervals starting from the day of their appearance in the field.

Weekly populations of *A. gossypii* and *H. vigintioctopunctata* on brinjal were subjected to time series analysis (Croxtan and Cowden, 1964). The seasonal indices of populations for different fortnight of the crop season were computed.

3.1.2 Meteorological parameters and their association with *A. gossypii* and *H. vigintioctopunctata* populations

Daily weather data, viz, temperature (maximum and minimum), relative humidity (morning and evening), total rainfall, number of rainy days and hours of bright sunshine for the entire period of study were collected from the Meteorological Observatory of the Department of Meteorology, Assam Agricultural University, Jorhat (Appendix I and II). The relationships between the meteorological factors and the population densities of these pests were worked out by correlation analysis (Snedecor and Cochran, 1967). Pooled correlation co-efficient for the year 1998-99 and 1999-2000 was calculated by following the methods described by Gomez and Gomez (1984).

3.1.3 Studies on natural enemies

Natural enemies of *A. gossypii* and *H. vigintioctopunctata* were recorded as and when observed on the selected plants while sampling population of these two pests.

The predatory coccinellids of *A. gossypii*, were collected from the field and their predatory efficiency were studied (Saharia, 1981) under laboratory conditions. The adult predatory coccinellids collected from the field were kept individually in glass chimneys (23 cm x 7.5 cm) without any food for 24 hours. These starved beetles were offered 10, 20, 30, 40 and 50 numbers of *A. gossypii* individually in separate chimneys, which was replicated thrice. The top open ends of the chimneys were covered with fine muslin cloth, held tight with rubber band. The numbers of aphid consumed in 24 hours were recorded.

Predatory efficiency was calculated as :

$$\text{Predatory efficiency (\%)} = \frac{\text{Number of prey consumed}}{\text{Number of prey offered}} \times 100$$

Other predators of *A. gossypii* encountered in the field were also studied in the same manner.

Clusters of suspected parasitized eggs of *H. vigintioctopunctata*, collected from the field on each sampling data were kept alongwith the substrate in glass chimneys (23 cm x 7.5 cm) for emergence of parasitoids. The chimneys were covered with muslin cloth at the open end.

Ten parasitized larvae of *H. vigintioctopunctata* collected from the field were placed singly over a brinjal leaf of medium maturity, fixed at the top of a water filled

glass tube (7.5cm x 4.5cm) with a thermocork to ensure ready supply of water to the leaf petiole, which lengthened the turgidity of the leaf. Everyday, leaves were replaced by fresh leaves. All 10 such tubes were covered by chimneys fitted with muslin cloth at the open end. Observations were taken daily to record the emergence of parasitoids.

Ten parasitized pupae of *H. vigintioctopunctata* collected from the field along with the substrate were kept singly over a filter paper inside a covered petridish (15 cm) under laboratory conditions. All the pupae were observed daily for possible emergence of parasitoids.

The relationships of extent of parasitization and predator population density with pest population density were worked out by correlation studies (Snedecor and Cochran, 1967). Pooled correlation co-efficients for the year 1998-99 and 1999-2000 were calculated by following the methods given by Gomez and Gomez (1984).

3.1.3.1 Identification of natural enemies

Field collected specimens of predators were dry preserved and parasitoids were wet preserved in 70% alcohol. The coccinelid predators were identified in the Zoological Survey of India, Calcutta, whereas the hymenopteran parasitoids were got identified from the Department of Zoology, University of Calicut, Kerala.

3.2 Distribution pattern of *A. gossypii* and *H. vigintioctopunctata*

Distribution patterns of *A. gossypii* and *H. vigintioctopunctata* were studied in the brinjal crop used for studying the population dynamics (described under section 3.1.)

3.2.1 Sampling methods

Two plant inspection methods of sampling for both *A. gossypii* and *H. vigintioctopunctata* were adopted for ascertaining the distribution pattern of different stages of these insects. In all the sampling methods, population of the immature stages and adults were counted *in situ* at different growth stages of the crop. The first sampling was done on the day of appearance of these pests in the field. A description of different stages of the brinjal crop is presented in Appendix IV.

3.2.1.1 Sampling method for *A. gossypii*

PI(A)-1: Fifteen plants were selected randomly (5 plants from each plot) and in each plant two leaves each from top, middle and bottom strata of the canopy were taken as sampling unit. At the seedling stage of the crop (up to 5 leaf stage), whole plant was taken as a unit. The nymphs and adults of *A. gossypii* from each selected plant and sampling unit were counted.

PI(A)-2: From 10 randomly selected plants (at least 3 plants from each plot), three tender leaves, three medium leaves and three coarse leaves per plant were taken as sampling unit. Whereas in case of seedling, whole plant was taken as sampling unit. The nymphs and adults on each leaf were counted.

3.2.1.2 Sampling method for *H. vigintioctopunctata*

PI(L)-1: From 30 randomly selected plants (10 plants from each plot), two branches were selected. Before attaining two-branch stage, whole plant was selected as one sampling

unit. Number of leaves, number of infested leaves, number of grubs, pupae, adults and eggs of the beetle per unit were counted.

PI(L)- 2: From 20 randomly selected plants (at least 6 plants per plot), one branch from top, one from middle and one from bottom were taken as sampling unit. Before attaining three branch stage, whole plant was taken as one sampling unit. Number of leaves, number of infested leaves, number of grubs, pupae, adults and eggs per unit were counted.

3.2.1.3 Sampling occasions

Samples were drawn at fortnightly intervals (corresponding to each phenological stage of the crop) starting from the day of appearance of these pests in the field. Samples were taken during morning hours (7 am to 10 am).

3.2.2 Sampling statistics for distribution pattern of *A. gossypii* and *H. vigintioctopunctata*

The mean population densities of *A. gossypii* and *H. vigintioctopunctata* by different sampling methods were worked out on each sampling date. Variances were also calculated for each sampling date. These population means and variances were subjected to analyses outlined by Southwood (1978).

3.2.2.1 Variance to mean ratio

Variance to mean ratio (S^2/\bar{X}) is the simplest way to determine the pattern of distribution. When $S^2 = \bar{X}$ (Ratio equal to 1), it indicates random distribution. When

$S^2 < \bar{X}$ (ratio < 1), the distribution is regular. Finally, when $S^2 > \bar{X}$ (ratio > 1), the distribution pattern is contagious or clumped or aggregated.

3.2.2.1 Dispersion parameter or exponent-k

The negative binomial distribution is described by two parameters, the mean and the exponent-k. The parameter 'k' is a measure of the amount of clumping. The following formula given by Southwood (1978) was used to determine the exponent-k.

$$k = \frac{\bar{X}^2}{S^2 - \bar{X}} \quad \text{where, } \begin{array}{l} \bar{X} = \text{mean} \\ S^2 = \text{variance} \end{array}$$

If $k \rightarrow \infty$, then clumping is low and there is a tendency towards randomness. When $k < 8$, then it indicates high amount of aggregation. If $k < 1$ or fractional then the distribution is logarithmic or highly clumped.

3.2.2.3 Co-efficient of variation

The smaller the 'k' value, greater is the extent of aggregation, whereas larger than 8 indicates that the distribution is approaching poisson. This may be appreciated from the relationship of 'k' to the co-efficient of variation.

$$CV = \frac{\sqrt{S^2}}{\bar{X}} \quad \text{where, } \begin{array}{l} S^2 = \text{variance,} \\ \bar{X} = \text{mean} \end{array}$$

3.2.2.4 Index of mean crowding

The index of mean crowding (X^*) was calculated following the formula given by Lloyd (1967).

$$X^* = \bar{X} + \left[\frac{S^2}{\bar{X}} - 1 \right] \quad \text{where,} \quad \begin{array}{l} S^2 = \text{variance,} \\ \bar{X} = \text{mean} \end{array}$$

If the value of $X^* > \bar{X}$, then it signifies contagious distribution and if $X^* \leq \bar{X}$, then it indicates random and regular distributions, respectively.

3.2.2.5 Lloyd's index of patchiness

Lloyd (1967) expressed the patchiness of distribution as the ratio of the mean crowding (X^*) to mean density (\bar{X}) i.e.,

$$\text{Patchiness Index} = \frac{X^*}{\bar{X}}$$

If the value of this index is equal to unity, then it indicates random distribution and when the value of index is greater than or smaller than unity, then it signifies contagious and regular distribution, respectively.

3.2.2.6 Index of clumping

Distribution pattern of a population can be found out by calculating the index of clumping (I_{DM}) given by David and Moore (1954).

$$I_{DM} = \frac{S^2}{\bar{X}} - 1 \quad \text{Where,} \quad \begin{array}{l} S^2 = \text{variance} \\ \bar{X} = \text{mean} \end{array}$$

Positive I_{DM} value signifies contagious distribution while negative value signifies regular distribution. Whereas random distribution is indicated by zero I_{DM} values.

3.2.2.7 Mean colony size

Tanigoshi *et al.* (1975) gave the formula of mean colony size (C^*) as

$$C^* = X^* + 1 \quad \text{Where, } X^* = \text{mean crowding}$$

Lloyd called it as mean demand. This concept is useful, when the sample unit contains an entire colony.

3.2.2.8 Mean clump size

The cause of aggregation can be confirmed by using the formula of mean clump size (λ) of Arbous and Kerrich (1951)

$$\lambda = \frac{\bar{X}}{2k} V$$

Where, \bar{X} = mean, V = a function with a χ^2 distribution at $2k$ degrees of freedom at $P = 0.05$.

If $\lambda < 2$, then clumping is due to micro-environmental heterogeneity, and when $\lambda > 2$, then the clumping is caused by both environmental heterogeneity and intrinsic behaviour of the insect.

3.2.2.9 Iwao's patchiness regression

The regression method introduced by Iwao (1968) involves the linear equation

$$X^* = \alpha + \beta \bar{X}$$

Where, X^* = Lloyd's index of mean crowding (dependent variable)

\bar{X} = mean density (independent variable)

α = the intercept on the ordinate or index of basic contagion

β = the slope of the regression line when X^* is regressed on the \bar{X}
or density contagiousness co-efficient.

If $\alpha \geq 0$ and $\beta \geq 1$, then distribution is contagious and for regular distribution $\alpha \leq 0$ and $\beta \leq 1$. Student's t-tests are employed to determine if $\alpha = 0$ or 1, or if $\beta = 0$ or 1.

3.2.2.10 Taylor's power law

The spatial distribution of most organisms can be described by Taylor's power law which provides a better description of variance mean relationships for a particular insect than does Iwao's patchiness regression. This variance and mean relationship was given by Taylor (1961) as a linear equation,

$S^2 = a\bar{X}^b$, where S^2 = variance, \bar{X} = mean, a = sampling factor (constant for a species) b = measure of aggregation (constant for a species). The equation is further illustrated for convenience, which fitted as a regression equation in logarithms as expressed as

$$\log (S^2) = \log a + b \log \bar{X},$$

Where, $\log a$ = intercept , b = regression co- efficient or index of aggregation (constant for a species) and show that, if $b > 1$, it indicates an aggregated distribution; $b = 1$, a random distribution and $b < 1$, a regular distribution.

The fit of each data set to the linear regression method for both Taylor's power law and Iwao's patchiness regression method were evaluated by co- efficient of determination (R^2) value (Johnston, 1963).

3.3 Optimum number of samples

The optimum number of samples to be drawn for estimating insect population depends on the degree of accuracy desired. The following model of Ruesink (1980) was adopted to calculate the optimum number of samples (N) for reasonably accurate estimation of species density from a population, which is more or less homogeneously distributed.

$$N = \frac{S^2}{C^2 \bar{X}^2}$$

Where, N = number of samples

S^2 = variance

C = desired level of accuracy expressed as a decimal (0.1 or 0.25).

\bar{X} = mean number of individuals per sample

When the distribution is a clump and followed a negative binomial pattern, then the optimum sample number was worked out with reliability by the following formula given by Ruesink (1980).

$$N = \frac{k + \bar{X}}{C^2 k \bar{X}}$$

Where, N = number of samples

C = desired level of accuracy expressed as a decimal (0.1 or 0.25)

\bar{X} = mean number of individuals per sample.

k = exponent or dispersion parameter

3.4 Varietal resistance of brinjal variation against *A. gossypii* and *H. vigintioctopunctata*

The field and laboratory studies on varietal resistance of brinjal against *A. gossypii* and *H. vigintioctopunctata* were carried out simultaneously in the experimental field and in the laboratory, respectively, of the Department of Entomology, Assam Agricultural University, Jorhat, during 1998-99. Some of the laboratory studies were carried out in the Department of Agronomy, Department of Horticulture and Department of Biotechnology, College of Agriculture, Assam Agricultural University, Jorhat. A few biochemical analyses were done in the chemical laboratory of the Regional Research Laboratory, Jorhat. The materials used and the methods followed for the field and laboratory studies are described below.

Sixteen varieties of brinjal were tested for resistance against the two pests (Plate 5 – 20). Five of these varieties viz, Pusa Kranti, Pusa Purple Long, Pusa Bhairav, Pant Samrat and JC-2 are recommended for cultivation in Assam, two are local varieties viz, 'Kharua Bengena' and 'Sagalisingia', and the remaining nine varieties were found to be promising in some other states of India. The sources of seed material and status of these varieties are presented in Appendix V.

3.4.1 Infestation and population build up of *A. gossypii* and *H. vigintioctopunctata* on different brinjal varieties

3.4.1.1 Site and crop season

A high land measuring 4 m x 40 m (160 m²) of the experimental field of the Department of Entomology, Assam Agricultural University, Jorhat was selected for conducting the field experiment. This experiment was carried out on September sown crop (winter crop) during 1998 - 99.

3.4.1.2 Seedling raising, transplanting and interculture operations

Seeds of the sixteen cultivars of brinjal used in this experiment were sown on 3 September. Forty days old seedlings were transplanted on 14 October 1998 in the well-prepared field with a spacing of 75 cm x 60 cm. Each entry was randomly planted in three rows of 4 m accommodating 6 plants per row. Each row was considered as a replication (Rajendran and Gopalan, 1998). The distance from the ridge of the plot to the outermost plant was 50 cm on all sides. On one side of the border, along the whole length of the varietal trial experiment, at a distance of 1 m apart, a susceptible brinjal variety,

Pusa Purple Long was planted. This encouraged uniform natural inoculation of both the insects into the varieties. All the intercultural operations were followed as per package of practices (Anon, 1997). However, to attract and maintain natural infestation of these insects, no plant protection practices were adopted in the experimental plots.

3.4.1.3 Sampling technique for *A. gossypii*

For recording the natural infestation and population build up of *A. gossypii* on brinjal varieties, the plant inspection method was followed. For this, three plants per row of each entry were selected randomly and aphid population on six leaves (2 top, 2 middle and 2 bottom) per plant were counted *in situ*. Observations on aphid population density and percent intensity were recorded at fortnightly intervals starting from the crop age of 135 - 140 days during which incidence of aphid was observed in all the brinjal varieties. Observations were continued for eight fortnights till the first week of April. The screening and ranking of varieties against *A. gossypii* were done based on following scale.

Rank	Population density of <i>A. gossypii</i>/leaf
Highly resistant	≤ 1.0
Resistant	$> 1.0 - \leq 1.2$
Moderately resistant	$> 1.2 - \leq 1.6$
Moderately susceptible	$> 1.6 - \leq 2.4$
Susceptible	$> 2.4 - \leq 4.0$
Highly susceptible	> 4.0

3.4.1.4 Sampling technique for *H. vigintioctopunctata*

Plant inspection method was followed to record natural infestation and population build up of *H. vigintioctopunctata* on brinjal varieties. For this, three plants per row of each entry were chosen randomly to count the population of larva, pupa and adult of *H. vigintioctopunctata*. The number of infested leaves on two branches per selected plant were also counted *in situ*.

Observations were taken at fortnightly intervals starting from the crop age of 155 - 160 days, when the beetle population in all the brinjal varieties were observed. The screening and grading of varieties against *H. vigintioctopunctata* were done based on the following scale.

Rank	Population density of <i>H. vigintioctopunctata</i> /branch
Highly resistant	≤ 0.5
Resistant	$> 0.5 - \leq 1.0$
Moderately resistant	$> 1.0 - \leq 2.0$
Moderately susceptible	$> 2.0 - \leq 4.0$
Susceptible	$> 4.0 - \leq 8.0$
Highly susceptible	> 8.0

3.4.2 Comparative biology of *A. gossypii* on different brinjal varieties

The life history of *A. gossypii* was studied on different brinjal varieties under prevailing room temperature and humidity conditions (Appendix III) of the laboratory to determine varietal effects on different biological parameters of the aphid. Leaves of each

of the 16 varieties were used to rear the aphids. The biological parameters were recorded from two successive laboratory generations.

A few gravid apterous females of *A. gossypii* were collected from the brinjal field and were released in a covered petridish (15 cm) containing brinjal leaves to get sufficient numbers of nymphs.

Three new born nymphs were transferred individually with a soft camel hair brush onto a fresh medium aged leaf of each of the brinjal varieties. The leaf was fixed on a thermocol plug of a glass tube (2.5 cm x 6 cm) in such a manner that the leaf petiole remained immersed in water of the tubes (Plate 1). It ensured leaf turgidity and freshness for a longer period of time. The tube was covered by a glass chimney (22 cm x 10 cm). The open end of the chimney was covered with fine muslin cloth so that the aphids could not escape (Plate 2). Four replications were kept for each variety. Leaves were renewed whenever necessary. A multi-chambered leaf carrying box (Plate 3) made of thermocol was used to avoid possible evaporation loss from leaves during transit from field to laboratory. Each of the sixteen chambers of this box was meant for the leaves of a particular variety and padded with moist cotton before use. Each chamber was marked with the proper crop variety code. The box was covered tightly with a thermocol cover sheet by adhesive and brought to the laboratory for renewal of old leaves.

Observations on different biological parameters of the aphid were recorded twice daily (9 am and 3 pm). The parameters recorded were – developmental period, reproductive period, pre-reproductive period, post reproductive period, fecundity,



Plate 1. A brinjal leaf fixed in a specimen tube for rearing *A. gossypii* and *H. vigintioctopunctata*

Plate 2. Specimen tube - chimney assembly for rearing of *A. gossypii* and *H. vigintioctopunctata*

Plate 3. A leaf carrying box.

Plate 4. Cages with cultures of *H. vigintioctopunctata*

reproductive rate, adult longevity and nymphal survival. The study was continued till completion of the second generation.

3.4.3 Comparative biology of *H. vigintioctopunctata* on different brinjal varieties

The life history of *H. vigintioctopunctata* was studied on the 16 brinjal varieties under normal laboratory temperature and humidity conditions (Appendix III) to ascertain possible effects of plant varietal characters on the biology of the beetles.

A field collected egg mass of *H. vigintioctopunctata* was kept for hatching with the leaf substrate in a petridish (15 cm). Upon hatching, the first instar larvae were transferred into fresh medium aged leaves fixed on specimen tubes (2.5 cm x 4 cm) covered with chimneys as described in section 3.4.2. Laboratory culture of the *H. vigintioctopunctata* was also maintained inside cages to get ready supply of the species (Plate 4).

In this way, three larvae per leaf were reared separately by providing leaves of respective varieties till they became full-grown. Leaves were renewed daily. Five replications were kept for each variety.

Larval period and the per cent larval survival were recorded. The pupal period was recorded on newly formed pupae transferred into covered petridishes (10 cm). Growth index was computed following Patil *et al.* (1986). Adult emergence was also recorded.



- Plate 5.** A plant of brinjal variety, Pusa Kranti
Plate 6. A plant of brinjal variety, Pusa Bhairav
Plate 7. A plant of brinjal variety, Pusa Purple Long
Plate 8. A plant of brinjal variety, Pusa Bindu
Plate 9. A plant of brinjal variety, Pusa Uttam
Plate 10. A plant of brinjal variety, KS-331
Plate 11. A plant of brinjal variety, Aruna
Plate 12. A plant of brinjal variety, Arka Nidhi



- Plate 13. A plant of brinjal variety, Arka Keshav
 Plate 14. A plant of brinjal variety, Muktakeshi
 Plate 15. A plant of brinjal variety, Neelam Long
 Plate 16. A plant of brinjal variety, JC-2
 Plate 17. A plant of brinjal variety, "Sagalisingia"
 Plate 18. A plant of brinjal variety, Pant Samrat
 Plate 19. A plant of brinjal variety, AB-2
 Plate 20. A plant of brinjal variety, "Kharua Bengena"

One pair of male and female adults obtained from rearing on each variety was released in a glass chimney provided with fresh brinjal leaves of respective varieties. Three replications were maintained and observations were taken daily twice to record mating period, pre-oviposition period, oviposition period, fecundity and adult longevity.

For obtaining sex ratio in laboratory generations, a cluster of eggs (approximately 20 - 30 eggs) along with the leaf substrate of each variety were kept in a separate chimney and the hatched out larvae were allowed to feed on fresh brinjal leaves till they attained adult stage. After adult emergence, males and females were identified and counted for each variety.

Sex ratio in the field populations was obtained by collecting 10 - 15 numbers of adults from each plot of brinjal varieties in separate specimen tubes and counting the males and females after killing them in the laboratory. Three observations were taken at different time interval.

3.4.4 Leaf area consumption of *H. vigintioctopunctata* on different varieties of brinjal

The feeding experiment was conducted with freshly emerged first instar larvae of *H. vigintioctopunctata* obtained from different varieties of brinjal in the laboratory experiment described under 3.4.3. A single larva, after 6 h starvation was allowed to feed on a leaf of the respective brinjal variety. The leaf was kept in a 'specimen tube - chimney assembly' (Plate 2) as described elsewhere. The experiment was conducted in a similar manner with the larvae of other instars and the adults as well. All the instars and

the adult were prestarved for 6 hours after moulting/emergence. Renewal of leaves were done daily.

The leaf area consumed for each larval instar/adult were recorded after 48 hours of release. The consumed leaf area was measured by graph paper method (Sambandam *et al.*, 1972). The outline of the area consumed was marked on a transparent butter paper and then measured by using a graph sheet.

3.5 Mechanism of resistance

3.5.1 Morphological resistance

To find out the possible association of morphological characters of the varieties as antixenosis factors with resistance against *A. gossypii* and *H. vigintioctopunctata*, leaf thickness, pilosity, leaf area, foliage population, angle of leaf attachment, vein and veinlet density, leaf colour and stomatal density of different brinjal varieties were recorded.

3.5.1.1 Leaf thickness

Three leaves, one each from top, middle and bottom of the canopy of each variety were collected at flowering stage. The leaves were cut into small bits. These bits were inserted into a slit made in a small sized potato tuber. Five sections of the leaf were obtained by cutting thin slices of the potato with a sharp razor blade. Six fine sections (2 each from leaf of each strata) of leaf of each variety were then placed under a compound microscope. Thickness of thin leaf sections was measured with stage and ocular micrometers.

3.5.1.2 Leaf pilosity

To determine the pilosity of brinjal varieties, three tender, three medium and three old leaves from each variety were collected from the field at flowering stage. The leaves were thoroughly cleaned and examined under a stereo-binocular microscope to record the number of hairs present per unit area on both surfaces of the leaf. For this, a square shaped portion of size 3 mm x 3 mm was removed from a plain paper which was then placed over the leaf under microscope. The number of hairs (pilosity) per 9 sq. mm of leaf surface of each variety and each age group were counted.

3.5.1.3 Leaf area

To determine the leaf area, three tender, three medium aged and three old leaves of each variety were collected at flowering stage and were placed over a graph paper (1 small square = 1 mm²) and their peripheries were drawn on the graph paper with a pencil. The number of squares present within the periphery was counted which gave the area in mm².

3.5.1.4 Foliage population

To determine the foliage population, three plants of each variety were randomly selected in the field and the leaves present per plant were counted *in situ*.

3.5.1.5 Angle of leaf attachment

To determine the angle of attachment of leaves with the stem, two plants of each variety were selected randomly in the field. The angle of attachment of leaves at the top, middle, and the bottom canopy were measured with the help of a protractor *in situ*.

3.5.1.6 Vein and veinlet density

To determine the vein and veinlet density of brinjal varieties, three leaves (one each from top, middle and bottom of canopy) of each variety were collected at the flowering stage from the experimental plots. The leaves were thoroughly cleaned and placed under a cylindrical hand lens (10X) having an opening of 7 mm x 5 mm at the distal end and the observed veins and veinlets were counted.

3.5.1.7 Leaf colour

In order to determine the actual leaf colour of different brinjal varieties, two fresh leaves from the middle of the canopy was collected from the field at the flowering stage of the crop. The leaf was placed under a Lovibond Tintometer (Model E-AF 900) for recording the intensity of the red, yellow and blue colours. The colour intensities of both the leaf surfaces were recorded and the average was expressed in Lovibond scale.

3.5.1.8 Stomatal density

For determining the number of stomata present on leaves of different brinjal varieties, three leaves (one each of tender, medium and old age) were collected from the experimental field at the flowering stage. To determine the stomatal density the adhesive

peeling technique of Bai and Jos (1981) was used. The technique involved smearing a small part of the leaf (under surface) with a resin adhesive into a thin film, which was peeled off after an hour. The impressions on the adhesive were directly examined under a stereo-binocular microscope (at 40 X) and the number of stomata were counted.

3.5.2 Biochemical resistance

To identify possible association of antibiosis factors in brinjal varieties with resistance against *A. gossypii* and *H. vigintioctopunctata*, a quantitative estimations of biochemical constituents of leaves of different brinjal varieties, such as nitrogen, crude protein, potash, crude fibre, moisture, tannin, phenols, free amino acids and carbohydrate contents were determined, following standard procedures as described below:

3.5.2.1 Sample preparation

Roughly equal proportions of uninfested leaf samples from top, middle and bottom canopy of each brinjal variety were collected at 90 days after transplanting. The leaves were washed thoroughly and one-fourth (by weight) of the sample was kept separately for determination of moisture content. The remaining three-fourth was oven dried at 70°C till constant weight was reached. The dried samples were ground into fine particles in an electric grinder and packed in separate polythene bags with proper varietal identification tag and stored in a desicator for biochemical analysis.

3.5.2.2 Nitrogen

Total nitrogen in the leaves of each variety of brinjal was estimated by Kjeltex Auto Analyser-1030. The total nitrogen estimated was expressed in percentage on dry weight basis.

3.5.2.3 Crude protein

The total crude protein content in the leaves of each brinjal variety was calculated by multiplying the total nitrogen content with the conversion factor 6.25 was expressed in percentage on dry weight basis.

3.5.2.4 Potash

Potassium content in the leaves of each brinjal variety estimated by flame photometry method using KCl as standard. Total potash content in leaf sample was estimated from standard curve in percentage basis on dry weight basis.

3.5.2.5 Crude fibre and moisture

The crude fibre and moisture contents of different varieties of brinjal leaves were determined by following A.O.A.C. (1980). Estimated contents were expressed in percentage on dry weight basis.

3.5.2.6 Tannin

Tannin contents in leaves of different brinjal varieties were estimated by modified Folin Denis method suggested by Swain and Hillis (1959) using tannic acid as standard. Tannin content was expressed in milligram per gram of samples.

3.5.2.7 Phenol

To determine the total phenol content in leaves of different brinjal varieties, the method of Bray and Thorpe (1954) was followed. In this method, the mixture of ethanol extract of leaves and Folin-ciocalteu reagent (indicator) in alkaline medium was used to measure its absorbance in spectrophotometer at 650 nm against a reagent blank and standard curve was prepared. From the standard curve, the concentration of phenols in the test samples was found out by using catechol as standard and expressed as milligram of phenols per 100 gram of sample.

3.5.2.8 Free amino acid

Total free amino acid contents in the leaf samples were estimated by ninhydrin method of Moore and Stein (1948) and it was expressed as milligram per gram of sample.

3.5.2.9 Carbohydrates

Determination of total carbohydrate present in leaves of each variety of brinjal was done by Anthrone method (Yem and Willis, 1954). The carbohydrate content (milligram of sugar) per 100 milligram of test sample was expressed as percentage.

CHAPTER IV

EXPERIMENTAL FINDINGS

Results of the studies carried out during 1998 – 1999 and 1999 – 2000, on the population ecology and varietal preference of *Aphis gossypii* Glover and *Henosepilachna vigintioctopunctata* (Fab.) on brinjal are presented in this chapter.

4.1 Seasonal population trend of *A. gossypii* on brinjal during 1998 – 1999

Data on mean population of nymphs and adults of *A. gossypii* are presented in Table 1. The trend of population build up at different crop stage (Appendix IV) and the meteorological data (Appendix I) for the study period are depicted in Figure 1. Plate 21 shows the infestation of *A. gossypii* on brinjal.

Incidence of *A. gossypii* commenced during the second week of October (14 October) *i.e.* one week after transplantation of the crop. The crop by then, was at the seedling (S_3) stage with a population density of 6.93, 3.67 and 0.40 nymphs, apterous adults and alate adults per plant, respectively. Till late vegetative (V_3) stage of the crop, the population trend of apterous aphids remained horizontal with not much fluctuations, although alate adults reached a small peak at this stage during the third week of December (23 December) with a population density of 0.93/6 leaves. Thereafter, in the first week of January (7 January), the population of nymphs and apterous adults attained a small peak of 14.40 and 5.26 per 6 leaves, respectively, when the crop was at flower

bud formation (R_1) stage. Immediately after this, a short decline in aphid population was observed which was followed by a sharp increase in population level of nymphs (38.00/6 leaves) and adults (18.93/6 leaves) to reach the climax in the fourth week of January (28 January) at flowering (R_2) stage of the crop. However, alate adult population of the aphid started declining from that stage and finally disappeared from the crop at the fruit initiation (R_3) stage, during the first week of February (4 February). The population of apterous aphids after reaching peak also started declining gradually from the same stage of the crop, which was accompanied by a sharp decline in population of nymphs to a level of 5.40/6 leaves in the third week of February (18 February). From this date of sampling, the alate adults appeared in the crop, which gradually reached its peak (1.86/6 leaves) in the first week of April (1 April), at the fruit ripening (R_5) stage of the crop and later on population declined to a level of 0.60/6 leaves in the last week of April (22 April), when the crop was at declining stage. However, population of nymphs and adults gradually decreased from the third week of February (18 February) onwards with few short rising and falling phases to reach a minimum population density level of 1.53 nymphs and 2.53 adults per 6 leaves, in the second week of April (15 April), when the crop was at a declining stage and by the next week nymphal population totally disappeared and adults numbered 0.53 and 0.60 per 6 leaves for apterous and alate form, respectively, at the last stage of the crop.

4.1.1 Impact of natural enemies on *A. gossypii* population during 1998 – 99

The predators, *Coccinella repanda* Thunb, *Menochilus sexmaculatus* F. and *Micraspis discolor* (F.) (Coleoptera : Coccinellidae) were recorded as potentially active

Table 1. Seasonal population trends of *A. gossypii* and its predators on brinjal during 1998-99

Sampling date	Crop growth stage	Population density of <i>A. gossypii</i>			Population density of predators (larva + adult/plant)			
		Nymph	Apterous adult	Alate adult	<i>C. repanda</i>	<i>M. sexmaculatus</i>	<i>M. discolor</i>	
October 14	S ₃	6.93	3.67	0.40	0.00	0.00	0.00	
21		4.40	1.80	0.33	0.00	0.00	0.00	
28		6.60	2.93	0.26	0.00	0.00	0.00	
November 4	V ₁	7.26	4.46	0.26	0.00	0.00	0.00	
11		9.47	3.80	0.33	0.00	0.00	0.00	
18		6.53	5.20	0.20	0.26	0.20	0.00	
25		4.80	3.20	0.13	0.13	0.40	0.00	
December 2	V ₂	5.40	4.46	0.26	0.26	0.73	0.00	
9		8.33	3.80	0.20	0.13	0.33	0.00	
16		7.46	3.20	0.20	0.26	0.46	0.00	
23		V ₃	3.81	4.67	0.93	0.20	0.60	0.00
31		9.73	3.00	0.67	0.20	0.33	0.00	
January 7	R ₁	14.40	5.26	0.67	0.13	0.33	0.20	
14		10.53	5.06	0.80	0.26	0.73	0.40	
21		R ₂	35.13	17.13	0.67	0.33	1.13	0.46
28		38.00	18.93	0.33	0.33	1.33	0.60	
February 4	R ₃	23.93	10.06	0.00	0.33	0.93	1.13	
11		20.06	7.93	0.00	0.53	0.66	0.93	
18		5.40	8.73	0.40	0.93	0.46	1.40	
25	R ₄	5.06	5.33	0.46	0.66	0.33	0.60	
March 4	R ₅	5.80	3.40	0.53	0.40	0.13	0.80	
11		5.13	2.60	0.66	0.66	0.26	0.53	
18		7.40	5.33	1.00	0.26	0.20	1.06	
25		3.73	2.73	1.53	0.00	0.26	1.53	
April 1	R ₆	1.00	3.53	1.86	0.13	0.26	0.66	
8		3.06	1.93	1.33	0.00	0.20	0.46	
15		1.53	2.53	1.46	0.00	0.00	0.46	
22		R ₇	0.00	0.53	0.60	0.00	0.00	0.00

Mean of 15 samples

* Data represent mean population/plant in S₃ stage and mean population/6 leaves/plant in other stages

natural enemies of *A. gossypii* (Plate 24, 25 and 26). The data on population of these three coccinellids are presented in Table 1 and the trends of their population buildup are shown in Figure 1. *C. repanda* and *M. sexmaculatus* appeared in the field at a low level of 0.26 and 0.20 numbers per plant, respectively, on 18 November when the prey density was at 6.53 nymphs, 5.20 apterous adults and 0.20 alate adults per 6 leaves. Thus, there existed a gap of five weeks between the appearances of prey and predators. However, *M. discolor* appeared in the field three weeks before the prey population approaching its peak, i.e. on 7 January, with a low population of 0.20 no./plant. The maximum population of *C. repanda*, *M. sexmaculatus* and *M. discolor* were 0.93, 1.33 and 1.53 per plant on 18 February, 28 January and 25 March, respectively, when prey population trend was at falling phase. Their population came down with the decline in prey population and finally disappeared by 8 April (*C. repanda*), 15 April (*M. sexmaculatus*) and 22 April (*M. discolor*), respectively. Both nymph and apterous adult population of *A. gossypii* showed significant positive correlation with *M. sexmaculatus* ($r = 0.795$, $P = 0.01$ for nymph and $r = 0.839$, $P = 0.01$ for adult), while adult apterous showed significant positive correlation with *C. repanda* ($r = 0.396$, $P = 0.05$) (Table 2). Alatae showed non-significant negative correlation with *M. sexmaculatus*.

No parasitoids could be recorded during the course of field studies.

4.1.2 Impact of meteorological factors on *A. gossypii* population during 1998–99

The correlations between mean population densities of *A. gossypii* and the weather parameters (Appendix I) were worked out and are presented in Table 3.

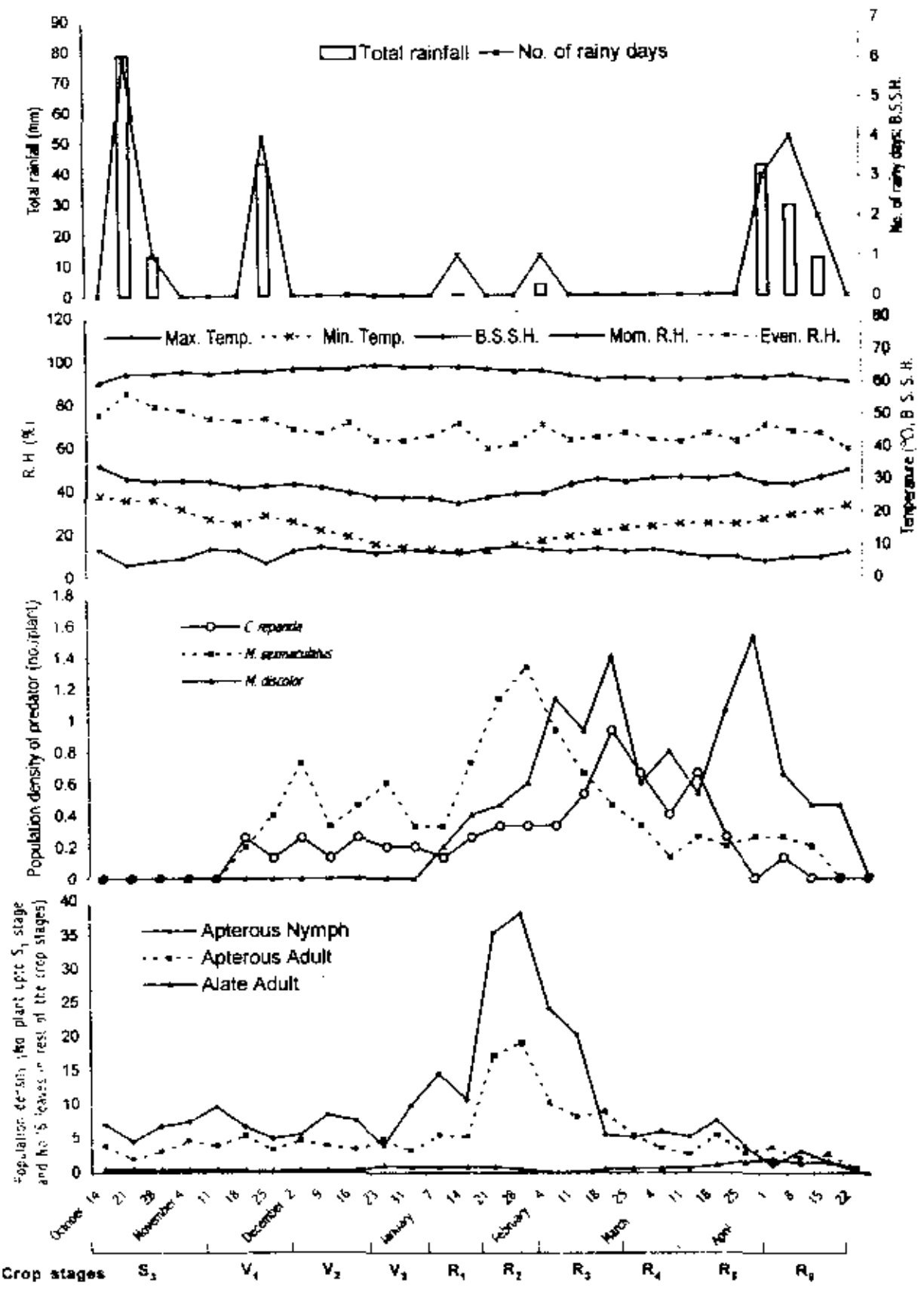


Fig. 1. Seasonal population trend of *A. gossypii*, *C. repanda*, *M. sexmaculatus* and *M. discolor* and meteorological parameters during 1998-99

Table 2. Relationship of *A. gossypii* population with predators, *C. repanda*, *M. sexmaculatus* and *M. discolor* population during 1998-99 and 1999-2000

<i>A. gossypii</i> population	Relation- ships statistics	Predator population during 1998-99			Predator population during 1999-2000		
		<i>C. repanda</i>	<i>M. sexmaculatus</i>	<i>M. discolor</i>	<i>C. repanda</i>	<i>M. sexmaculatus</i>	<i>M. discolor</i>
Nymphal population	r	0.194NS	0.795**	0.155NS	0.668**	0.450*	0.056 NS
	100r ²	3.764	63.200	2.402	44.622	20.250	0.300
	Z	0.196	1.080	0.159	0.808	0.486	0.060
	r _p				0.447*	0.665**	0.112 NS
	Y		1.732 + 20.869X		1.501 + 8.614X	2.226 + 4.300X	
Adult population	r	0.596*	0.839**	0.313NS	0.820**	0.647**	0.618**
	100r ²	15.682	17.392	9.797	67.240	41.860	38.190
	Z	0.419	1.219	0.326	1.159	0.770	0.724
	r _p				0.639**	0.767**	0.464*
	Y	3.601 + 6.943X	1.554 - 9.912X		0.716 + 2.677X	0.879 + 1.566X	0.915 + 1.541X
Nymph - Adult population	r	0.318NS	0.828**	0.226NS	0.737**	0.514*	0.177NS
	100r ²	7.896	68.558	5.107	54.316	26.522	3.100
	Z	0.289	1.180	0.230	1.643	0.570	0.180
	r _p				0.457*	0.716**	0.203 NS
	Y		3.155 + 30.964X		2.253 + 11.213X	3.138 + 5.814X	
Alate adult population	r	-0.262NS	-0.199NS	0.316NS	-0.353 NS	-0.416*	-0.435*
	100r ²	6.864	3.960	9.985	12.460	17.305	18.922
	Z	0.270	0.201	0.128	0.370	0.443	0.467
	r _p				0.302NS	0.300 NS	0.371 NS
	Y					0.670 - 0.664X	0.671 - 0.715X

NS : Not significant , * : Significant at P = 0.05, ** : Significant at P = 0.01

The key abiotic factors, viz., temperature (maximum and minimum), evening relative humidity, total rainfall and number of rainy days showed negative correlations with *A. gossypii* population. Morning relative humidity and bright sunshine hours showed positive correlation. However, all these correlations except those involving maximum and minimum temperatures and bright sunshine hours were not significant at $P = 0.05$.

The nymphal population registered significant negative correlation with both maximum temperature ($r = -0.517$, $P = 0.01$) and minimum temperature ($r = -0.584$, $P = 0.01$). Similarly, adult population also showed significant negative correlation with maximum temperature ($r = -0.445$, $P = 0.05$) and minimum temperature ($r = -0.567$, $P = 0.01$). Positive significant correlation existed between bright sunshine hours and the population of nymphs ($r = 0.478$, $P = 0.01$) and adults ($r = 0.480$, $P = 0.01$). Total aphid population (nymph + adult) too exhibited significant negative correlation with maximum temperature ($r = -0.503$, $P = 0.01$), minimum temperature ($r = -0.588$, $P = 0.01$) and significant positive correlation with bright sunshine hours ($r = 0.486$, $P = 0.01$).

Regression equations were computed (Table 3) for each significant relationship between aphid population and meteorological parameters. Regressions for nymphal population of *A. gossypii* were $Y = 59.008 - 1.758X$ (maximum temperature), $Y = 26.414 - 1.090X$ (minimum temperature) and $Y = -11.715 + 2.905X$ (bright sunshine hours). The regression equations for adult *A. gossypii* population were $Y = 24.426 - 0.681X$ (maximum temperature), $Y = 12.661 - 0.476X$ (minimum temperature) and $Y = -4.343 + 1.316X$ (bright sunshine hours). The regressions for overall mean population of this aphid

Table 3. Relationship of *A. gossypii* population with meteorological factors during 1998-99 and 1999-2000

Meteorological factors	Relationship statistics	<i>A. gossypii</i> population during 1998-99			<i>A. gossypii</i> population during 1999-2000		
		Nymph	Adult	Total (Nymph + Adult)	Nymph	Adult	Total (Nymph + Adult)
Maximum temperature	r	-0.517**	-0.445*	-0.503**	-0.107 NS	-0.242 NS	-0.142 NS
	100r ²	26.800	19.800	25.300	1.100	5.900	2.000
	Z	0.576	0.479	0.554	0.108	0.247	0.147
	r _p				-0.351 NS	-0.357 NS	-0.351 NS
	Y	59.008 - 1.758X	24.426 - 0.681X	83.424 - 2.438X			
Minimum temperature	r	-0.584**	-0.567**	-0.588**	0.058 NS	0.086 NS	0.067 NS
	100r ²	34.100	32.100	34.600	0.300	0.700	0.400
	Z	0.668	0.646	0.676	0.058	0.086	0.067
	r _p				-0.371 NS	-0.371 NS	-0.379 NS
	Y	26.414 - 1.09X	12.661 - 0.476X	39.079 - 1.566X			
R.H. (Morning)	r	0.356 NS	0.245 NS	0.327 NS	0.024 NS	-0.358 NS	-0.055 NS
	100r ²	12.700	6.000	10.700	0.100	12.800	0.300
	Z	0.375	0.250	0.340	0.024	0.374	0.055
	r _p				0.206 NS	0.298 NS	0.206 NS
	Y						
R.H. (Evening)	r	-0.278 NS	-0.344 NS	-0.304 NS	-0.185 NS	-0.277 NS	-0.215 NS
	100r ²	7.700	11.900	9.200	3.400	7.600	4.600
	Z	0.287	0.359	0.314	0.208	0.287	0.219
	r _p				-0.245 NS	-0.316 NS	-0.263 NS
	Y						
Total rain fall	r	-0.257 NS	-0.269 NS	-0.265 NS	-0.383 NS	-0.360 NS	-0.399 NS
	100r ²	6.600	7.200	7.000	14.700	13.000	15.900
	Z	0.264	0.274	0.276	0.405	0.375	0.424
	r _p				-0.316 NS	-0.310 NS	-0.330 NS
	Y						
No. of rainy days	r	-0.254 NS	-0.277 NS	-0.266 NS	-0.444 *	-0.161 NS	-0.409*
	100r ²	6.500	7.700	7.100	19.700	2.600	16.700
	Z	0.260	0.285	0.274	0.479	0.165	0.433
	r _p				-0.345 NS	-0.245 NS	-0.334 NS
	Y				4.338 - 0.751X		5.733 - 0.820X
Bright sunshine hours	r	0.478**	0.480**	0.486**	0.340 NS	0.004 NS	0.287 NS
	100r ²	22.700	23.000	23.600	11.500	0.000	8.200
	Z	0.519	0.523	0.533	0.344	0.000	0.296
	r _p				0.414*	0.277 NS	0.399*
	Y	-11.715 + 2.905X	-4.343 + 1.316X	-16.063 + 4.223X			

NS : Not significant, * : Significant at P = 0.05, ** : Significant at P = 0.01

were $Y = 83.424 - 2.438X$ (maximum temperature), $Y = 39.079 - 1.566X$ (minimum temperature) and $Y = -16.063 + 4.223X$ (bright sunshine hours).

4.2 Seasonal population trend of *A. gossypii* on brinjal during 1999–2000

Data on field population of *A. gossypii* recorded on different sampling dates are tabulated (Table 4). Figure 2 shows the population trend and meteorological data for the study period. Meteorological data are also appended in Appendix II.

Incidence of *A. gossypii* started soon after transplantation of the crop. The initial population were 2.73 nymphs, 1.20 apterous adults and 0.60 alate adults per plant at the seedling (S_3) stage of the crop, in the second week of November (11 November). At this same stage of the crop the nymphal population started rising up gradually to reach a density of 9.00/plant in the first week of December (2 December). But apterous adult population fluctuated in this period to attain population level of 1.40/plant on the same date of sampling. On the other hand, alate adult population initially increased to 1.33 /plant in the third week of November (18 November) and thereafter population started falling down gradually and finally disappeared from the crop at the mid-vegetative (V_2) stage, in the first week of January (6 January). At the initiation of early vegetative (V_1) stage on 9 December, nymphal population declined to 5.93/6 leaves, whereas apterous adult population bounced up to 1.71/6 leaves. Thereafter, the populations of apterous adult and nymph started declining gradually to a low population density of 0.46/6 leaves in the second week of January (13 January) at V_2 stage of the crop. From 20 January onwards, when the crop was approaching late vegetative (V_3) stage, the population of apterous morphs again increased gradually and attained peak population densities of

11.08 nymphs and 3.40 adults per 6 leaves at the fruit initiation (R_3) stage in the fourth week of February (24 February). However, in this period, alate adults reappeared with a very low population density and remained active for four weeks and again disappeared on 18 February when the crop was at R_3 stage. From first week of March, (2 March), the population of apterous aphids approached the falling phase of population trend and started declining every week. On 24 March, when the crop was at fruit ripening (R_5) stage, the populations of the apterous aphids stood at low levels of 1.36 nymphs and 1.53 adults per 6 leaves, by then the alate adults started reappearing on the crop with a population density of 0.16/6 leaves, which increased to reach its highest peak of 1.76/6 leaves in the first week of April (7 April). Thereafter nymphal population disappeared from the crop and apterous and alate adult populations stood at 0.16 and 0.53 / 6 leaves, respectively on the last sampling date (21 April).

4.2.1 Impact of natural enemies of *A. gossypii* during 1999 – 2000

The population trends of coccinellid predators, *C. repanda*, *M. sexmaculatus* and *M. discolor* are shown in Table 4 and Figure 2. The first two predators were observed after two and three weeks of appearance of *A. gossypii*, respectively, but later one was seen after ten weeks of appearance of the aphid. Then onwards, the predators were recorded on each sampling date. The populations of *C. repanda*, *M. sexmaculatus* and *M. discolor* attained the peaks of 0.78/plant (24 February), 1.06/plant (18 February) and 0.93/plant (9 March), respectively. Significant positive correlations were obtained between the *C. repanda* population with the nymphal population of *A. gossypii* ($r = 0.668$, $P = 0.01$), apterous adult population ($r = 0.820$, $P = 0.01$) and overall mean population of

Table 4. Seasonal population trends of *A. gossypii* and its predators on brinjal during 1999-2000

Sampling date	Crop growth stage	Population density of <i>A. gossypii</i>			Population density of predators (larva + adult./plant)			
		Nymph	Apterous adult	Alate adult	<i>C. repleta</i>	<i>M. senegalensis</i>	<i>M. discolor</i>	
November 11	S ₁	2.73	1.20	0.60	0.00	0.00	0.00	
18		3.66	1.40	1.33	0.00	0.00	0.00	
25		8.00	1.73	1.13	0.13	0.00	0.00	
December 2	V ₁	9.00	1.40	1.00	0.33	0.00	0.00	
9		5.93	1.71	0.86	0.33	0.13	0.00	
16		4.26	0.80	0.60	0.13	0.20	0.00	
23		1.93	1.26	0.20	0.06	0.26	0.00	
30		0.93	0.46	0.06	0.06	0.20	0.00	
January 6		V ₂	0.66	0.53	0.00	0.00	0.13	0.00
13	V _J	0.46	0.46	0.00	0.06	0.06	0.00	
20		2.86	0.93	0.46	0.13	0.20	0.06	
27		R ₁	4.26	1.00	0.86	0.26	0.53	0.26
February 3		R ₂	4.53	1.33	0.60	0.40	0.00	0.26
10	R ₃	4.96	1.67	0.20	0.58	0.83	0.48	
18		8.53	2.13	0.00	0.63	1.06	0.58	
24		11.08	3.40	0.00	0.78	0.92	0.63	
March 2		R ₄	2.53	2.26	0.00	0.56	0.66	0.53
9	1.93		1.80	0.00	0.23	0.39	0.93	
17	1.53		2.13	0.00	0.30	0.13	0.76	
24	R ₅		1.36	1.53	0.16	0.26	0.33	0.66
31	1.53		1.20	0.93	0.06	0.26	0.48	
April 7	R ₆	0.93	0.60	1.76	0.00	0.20	0.33	
14		0.00	0.26	1.46	0.00	0.00	0.13	
21		0.00	0.16	0.53	0.00	0.00	0.00	

Mean of 15 samples

* Data represent mean population/plant in S₃ stage and mean population/6 leaves/plant in other stages

the aphid (nymph + adult) ($r = 0.737$, $P = 0.01$). Significant positive correlations of *M. sexmaculatus* population were also found with nymphal population ($r = 0.450$, at $P = 0.05$), apterous adult population ($r = 0.647$, $P = 0.01$) and overall mean apterous population ($r = 0.514$, $P = 0.05$) and negative relation was found with alate adult population ($r = -0.416$, $P = 0.05$) of *A. gossypii*. *M. discolor* population exhibited significant positive correlation with apterous adult population ($r = 0.618$, $P = 0.01$) and negative correlation with alate adult population ($r = -0.435$, $P = 0.05$).

Combined correlation studies for both crop season signified that there were significant positive relationships between aphid population of apterous morphs with *C. repanda* and *M. sexmaculatus* population and apterous adult with *M. discolor* population. But no significant relationship existed between alate population with any of the coccinellid predators.

No parasitoids attacking *A. gossypii* could be known during the course of the studies.

4.2.2 Impact of meteorological parameters on *A. gossypii* population during 1999 – 2000

Data on population density of *A. gossypii* (Table 3) and meteorological data (Appendix II) are shown in Figure 2. Negative correlations existed between population of aphids with maximum temperature, evening relative humidity, total rainfall, no. of rainy days and adult and overall population with morning relative humidity. Positive correlations existed between population of aphids and minimum temperature as well as bright sunshine hours and nymphal population with morning relative humidity. However,

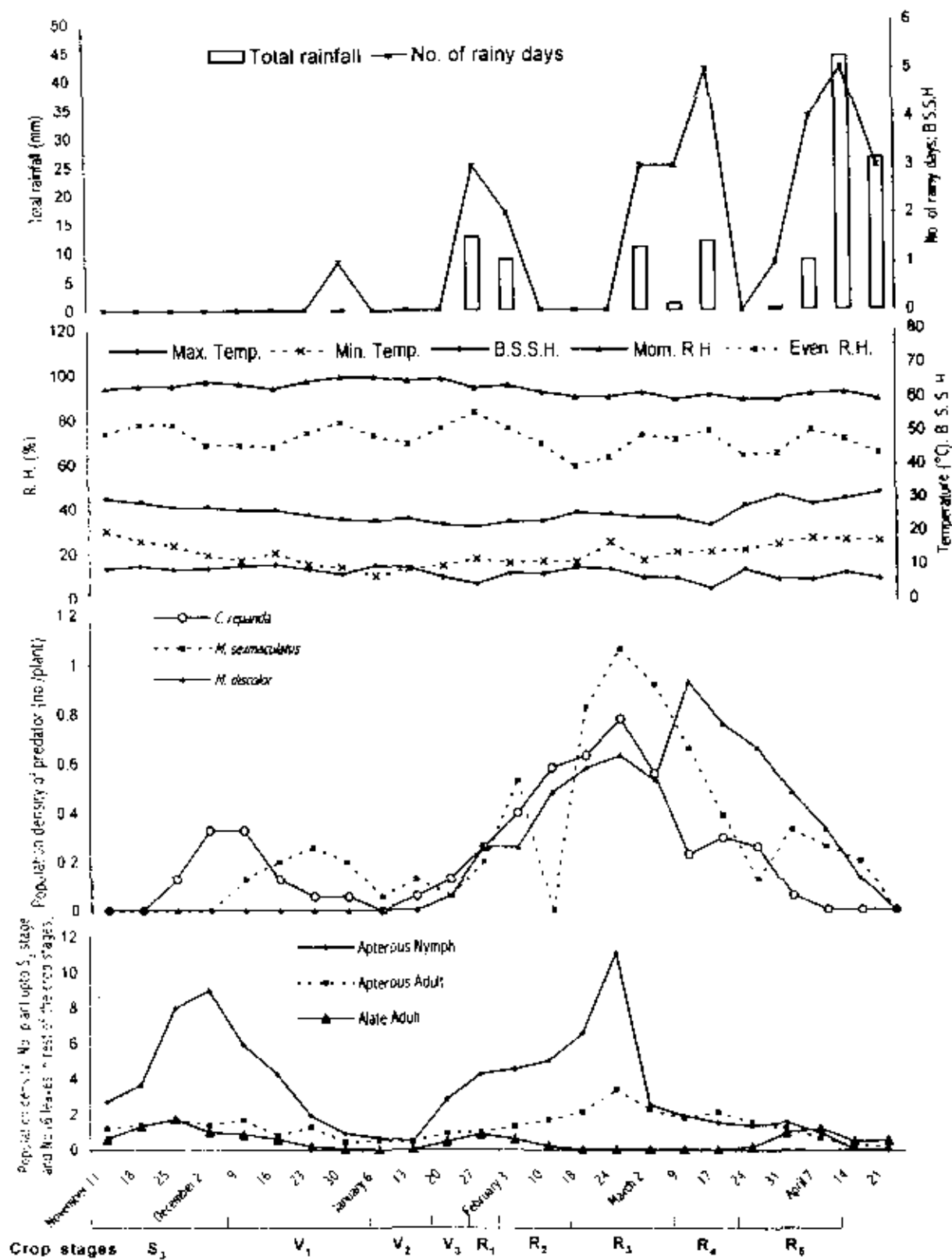


Fig. 2. Seasonal population trend of *A. gossypii*, *C. repanda*, *M. sexmaculatus* and *M. discolor* and meteorological parameters during 1999-2000

only number of rainy days showed significant correlation with the nymphal population ($r = -0.444$, $P = 0.05$) and overall mean aphid (nymph + adult) population ($r = -0.409$, $P = 0.05$). But the pooled correlation coefficient (r_p) for meteorological data and population of *A. gossypii* in 1998 – 99 and 1999 – 2000 showed that only bright sunshine hours had significant positive relations of with nymphal population ($r_p = 0.414$, $P = 0.05$) and overall (nymph + adult) aphid population ($r_p = 0.399$, $P = 0.05$). All other abiotic factors did not have any significant impact on fluctuation of aphid population during both the crop seasons.

4.3 Seasonal population indices of *A. gossypii* on brinjal

Seasonal index for population growth of *A. gossypii* was computed at fortnightly interval from population data of 1998 – 99 and 1999 – 2000 crop seasons. The indices are presented in Table 5 and Figure 3. The highest seasonal index of 302.40 was calculated on the second fortnight of January in which the peak population was recorded for the 1998 – 99 season. However, the peak of aphid population during 1999 – 2000 was delayed by two weeks. It is clear that the population of *A. gossypii* gradually increased from second fortnight of October till first fortnight of December and slightly dropped down in the second fortnight of December and again increased from then onwards to reach its peak in the second fortnight of January. Thereafter, population declined slowly to a level of its minimum population density in the second fortnight of April.

Table 5. Seasonal indices of *A. gossypii* population on brinjal

Month	Fortnight	*Aphid population density during crop season			Seasonal Index
		1998-1999	1999-2000	Mean	
October	II	3.03	0.00	1.51	45.50
November	I	4.26	1.51	2.88	86.75
	II	3.34	2.97	3.15	94.88
December	I	3.74	2.84	3.29	99.10
	II	3.74	0.81	2.27	68.40
January	I	6.12	0.35	3.23	97.30
	II	18.36	1.73	10.04	302.40
February	I	10.33	2.21	6.27	188.85
	II	4.20	3.85	4.02	121.10
March	I	3.03	1.35	2.19	65.96
	II	3.62	1.12	2.37	71.40
April	I	2.12	0.57	1.34	40.40
	II	1.11	0.23	0.67	20.20
Mean		5.15	1.50	3.32	100.00

* Number of aphids/plant during October and November (S₃ crop growth stage) and number of aphids/6 leaves/plant in rest of the months

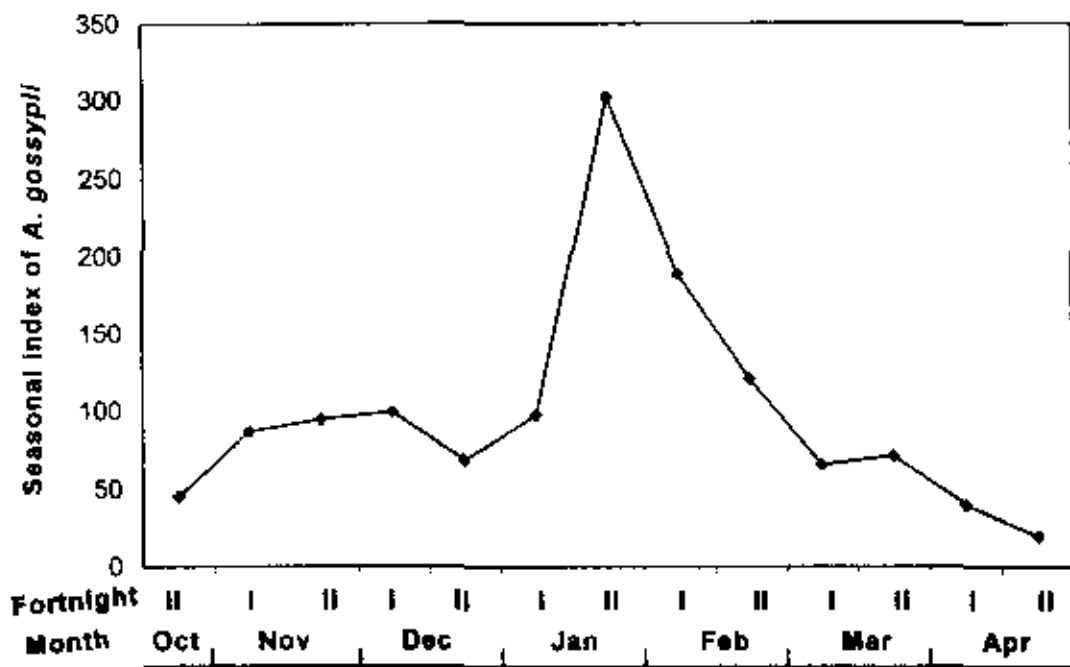


Fig. 3. Seasonal indices of *A. gossypii* population on brinjal (based on data of 1998-99, 1999-2000)

Table 6. Seasonal population trends of *H. vigintioctopunctata* and extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* on brinjal during 1998-99

Sampling date	Crop growth stage	Population density of <i>H. vigintioctopunctata</i> (no./2 branches)				Extent of parasitization (%)				
		Egg	Larva	Pupa	Adult	<i>Tetrastichus</i> sp.		<i>P. foveolatus</i>		
						Egg	Larva	Larva	Pupa	
October	14	S ₃	0.00	0.40	0.00	0.43	0.00	0.00	0.00	0.00
	21		0.00	0.80	0.00	0.46	0.00	12.50	0.00	0.00
	28		0.00	1.56	0.20	0.50	0.00	14.70	0.00	0.00
November	4		0.00	1.30	0.43	0.46	0.00	23.00	0.00	0.00
	11	V ₁	0.16	0.90	0.40	0.50	0.00	20.00	0.00	0.00
	18		0.23	1.10	0.60	0.46	0.00	14.50	0.00	16.60
December	25		0.23	1.40	0.33	0.80	0.00	12.80	4.30	24.25
	2	V ₂	0.00	0.93	1.06	0.36	0.00	8.60	4.30	21.70
	9		0.00	0.43	0.83	0.63	0.00	13.95	0.00	19.25
January	16		0.00	0.13	0.23	0.56	0.00	0.00	0.00	26.08
	23	V ₃	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00
	31		0.00	0.00	0.00	0.23	0.00	0.00	0.00	0.00
February	7	R ₁	0.13	0.00	0.00	0.40	0.00	0.00	0.00	0.00
	14		0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00
	21	R ₂	0.43	0.56	0.00	0.33	6.95	10.70	0.00	0.00
March	28		0.23	0.93	0.00	1.40	26.08	17.20	0.00	0.00
	4	R ₃	1.73	3.03	1.63	1.46	26.60	6.60	0.00	0.00
	11		0.63	4.20	1.83	1.93	25.40	7.15	3.10	21.85
April	18		0.96	10.33	1.03	1.76	31.25	8.30	6.20	44.60
	25	R ₄	0.60	13.97	2.23	2.73	33.30	26.20	6.40	47.50
	4		0.56	23.20	5.80	0.63	35.70	17.24	4.56	33.27
May	11	R ₅	0.46	13.03	6.56	2.76	34.78	10.74	6.60	40.09
	18		0.36	1.80	8.13	3.53	16.70	38.90	22.20	42.50
	25		0.30	2.40	1.00	2.03	10.00	19.16	0.00	23.00
June	1	R ₆	0.36	0.90	0.23	1.66	0.00	0.00	0.00	0.00
	8		0.13	0.40	0.26	0.63	0.00	0.00	0.00	0.00
	16		0.10	0.16	0.10	0.46	0.00	0.00	0.00	0.00
23	R ₇	0.00	0.00	0.00	0.30	0.00	0.00	0.00	0.00	

Mean of 30 samples

* Data represent mean population/plant upto V₁ stage, and mean population/2 branches in other stages

However, larval, pupal and adult populations attained their peaks on 4 March (23.20 larvae/2 branches), 18 March (8.13 pupae/2 branches) and (3.53 adults/2 branches) during fruit maturity (R_4) and fruit ripening (R_5) stages of the crop. From thereon, population came down gradually and finally disappeared from the crop, at the crop decline (R_7) stage in the fourth week of April (23 April) but adults still remained at a population of 0.30/2 branches on the last sampling date.

4.4.1 Impact of natural enemies on *H. vigintioctopunctata* population during 1998 – 99

Field collected eggs, larvae and pupae of *H. vigintioctopunctata* were found to be parasitized by two hymenopteran parasitoids, viz., *Tetrastichus* sp. (Eulophidae: Hymenoptera) and *Pediobius foveolatus* (Craw.) (Eulophidae : Hymenoptera) (Plate 27 and 28). The former parasitoid attacked both eggs and early instar larvae while the latter attacked both late instar larvae as well as pupae.

The data on extent of parasitization by both *Tetrastichus* sp. and *P. foveolatus* recorded during 1998 – 99 are shown in Table 6 and illustrated in Figure 4. The activity of *Tetrastichus* started after one week of appearance of the prey and ended at least three weeks before the disappearance of the host. The initial observation on 14 October showed no parasitic activity in the field. On the next sampling date (21 October), 12.50 per cent parasitization of the prey larvae was recorded, when the host population was 0.80 larvae/plant. However, during the entire period of observation, the extent of parasitization varied from 6.60 to 38.90 per cent. Maximum parasitization of larvae (38.90 per cent) was recorded in 18 March. However, egg parasitization was noticed from 21 January,

Table 7. Relationship of *H. vigintioctopunctata* population with the extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* during 1998-99 and 1999-2000

Host-parasite relationship	Relationship statistics	1998-99	1999-2000
<i>H. vigintioctopunctata</i> larval population vs. extent of parasitization by <i>Tetrastichus</i> sp.	r	0.303NS	0.549*
	100r ²	9.180	30.200
	Z	0.316	0.615
	r _p		0.414
	Y		0.219 + 0.150X
<i>H. vigintioctopunctata</i> larval population vs. extent of parasitization by <i>P. foveolatus</i>	r	0.343NS	0.542*
	100r ²	11.765	29.400
	Z	0.352	0.609
	r _p		0.430*
	Y		0.930 + 0.356X
<i>H. vigintioctopunctata</i> pupal population vs. extent of parasitization by <i>P. foveolatus</i>	r	0.675**	0.885*
	100r ²	45.600	78.322
	Z	0.820	1.400
	r _p		0.788**
	Y	0.060 + 0.087X	0.023 + 0.126X
Number of egg clusters of <i>H. vigintioctopunctata</i> vs. extent of parasitization by <i>Tetrastichus</i> sp.	r	0.690**	0.511*
	100r ²	47.600	26.100
	Z	0.852	0.568
	r _p		0.618**
	Y	0.126 + 0.019X	0.099 + 0.011X

NS : Not significant, * : Significant at P = 0.05, ** : Significant at P = 0.01

when population density of egg masses was at 0.43/2 branches. The peak egg parasitization (35.70 per cent) was recorded on 4 March, when the egg mass population (0.56/2 branches) was at falling phase. The parasitoid became almost untraceable from the first week of April.

The extent of parasitization by *P. foveolatus* was comparatively high and it accounted for about 16.60 to 47.50 per cent parasitization of the pupal host and 3.10 to 22.20 per cent larval host (Table 6 and Figure 4). The peak parasitization (47.50 per cent) was recorded on 25 February.

The correlation studies between prey population and the extent of parasitization indicated that there was positive and highly significant correlation between *Tetrastichus* sp. and egg mass population ($r = 0.690$, $P = 0.01$) and similar relation was also existed between *P. foveolatus* and pupal population ($r = 0.675$, $P = 0.01$) (Table 7).

In the course of study, no predator could be detected exercising regulatory power on population of *H. vigintioctopunctata*.

4.4.2 Impact of meteorological factors on *H. vigintioctopunctata* population during 1998 – 99

The mean population densities of *H. vigintioctopunctata* recorded on each sampling date were correlated with key meteorological factors (Appendix I) and results obtained are presented in Table 8.

Maximum temperature with larvae, pupae, adult and overall mean population and bright sunshine hours with larvae, pupae, eggs, and overall mean population showed

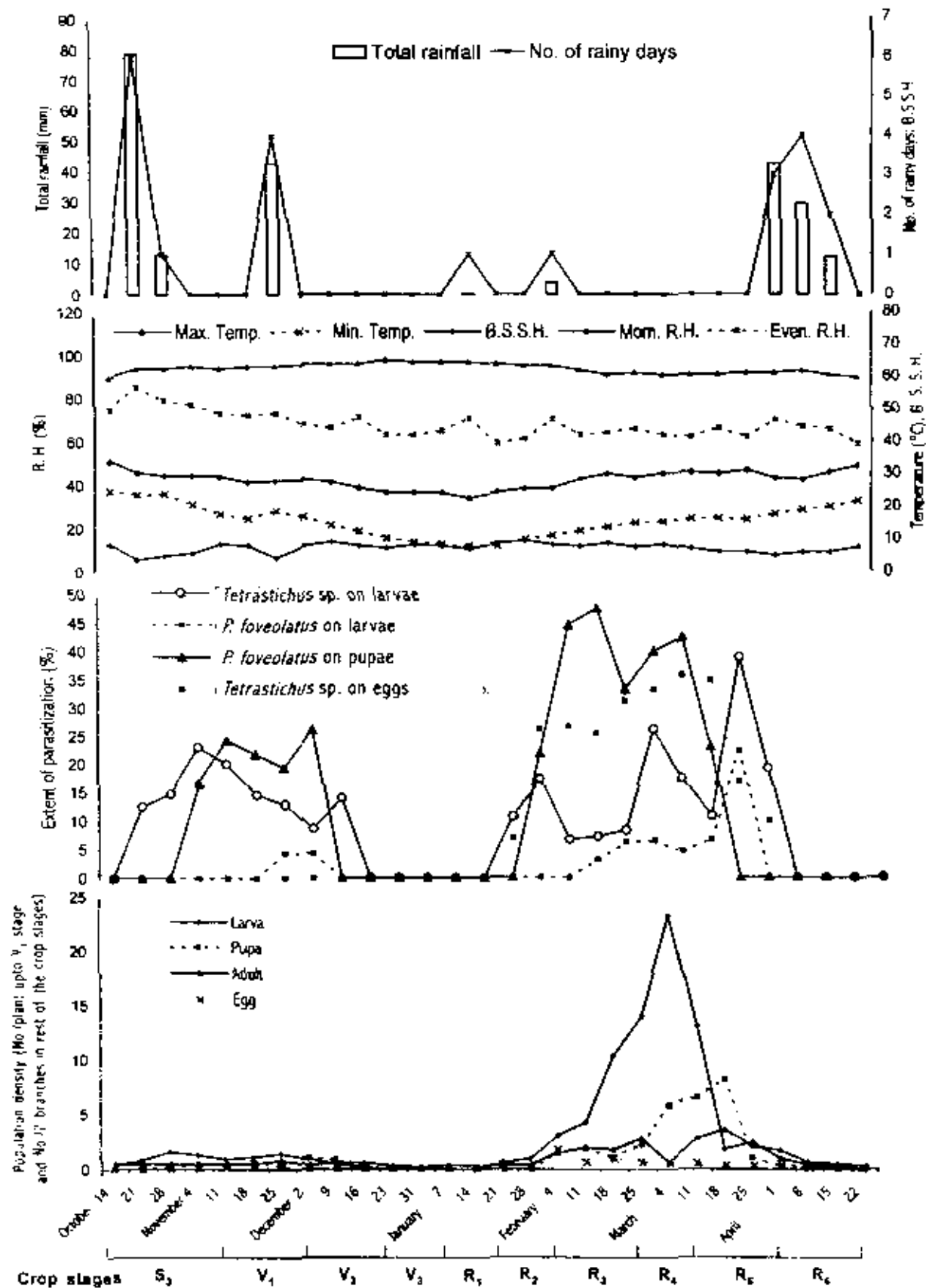


Fig. 4. Seasonal population trend of *H. vigintioctopunctata* and extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* and meteorological parameters during 1998-99

Table 8. Relationship of *H. vigintioctopunctata* population with meteorological factors during 1998-99

Meteorological factors	Relationship statistics	<i>H. vigintioctopunctata</i> population during 1998-99				
		Larva	Pupa	Adult	Egg	Larva+Pupa+Adult
Maximum temperature	r	0.272 NS	0.280 NS	0.301 NS	-0.023 NS	0.316 NS
	100r ²	7.400	7.800	9.000	0.100	10.000
	Z	0.279	0.289	0.312	0.023	0.324
	Y					
Minimum temperature	r	-0.028 NS	-0.004 NS	-0.010 NS	-0.273 NS	-0.018 NS
	100r ²	0.100	0.000	0.000	7.400	0.000
	Z	0.028	0.000	0.000	0.280	0.000
	Y					
R.H. (Morning)	r	-0.452*	-0.447*	-0.510**	-0.231 NS	-0.517**
	100r ²	20.500	20.000	26.000	5.400	26.700
	Z	0.489	0.482	0.564	0.254	0.573
	Y	100.078 - 1.035X	38.171 - 0.394X	18.978 - 0.192X		157.909 - 1.629X
R.H. (Evening)	r	-0.250 NS	-0.247 NS	-0.222 NS	-0.208 NS	-0.279 NS
	100r ²	6.300	6.100	4.900	4.300	7.800
	Z	0.258	0.256	0.228	0.216	0.285
	Y					
Total rainfall	r	-0.168 NS	-0.209 NS	-0.084 NS	-0.130 NS	-0.190 NS
	100r ²	2.800	4.400	0.700	1.700	3.600
	Z	0.170	0.214	0.084	0.137	0.197
	Y					
No. of rainy days	r	-0.199 NS	-0.232 NS	-0.120 NS	0.201 NS	-0.225 NS
	100r ²	4.000	5.400	1.400	4.040	5.100
	Z	0.205	0.236	0.124	0.208	0.229
	Y					
Bright sunshine hours	r	0.177 NS	0.007 NS	-0.138 NS	0.216 NS	0.104 NS
	100r ²	2.800	0.000	1.900	4.700	1.100
	Z	0.173	0.000	0.139	0.220	0.107
	Y					

NS : Not significant, * : Significant at P = 0.05, ** : Significant at P = 0.01

positive non-significant relations. However, maximum temperature (only eggs) and minimum temperature, evening relative humidity, total rainfall, number of rainy days (excluding eggs) and bright sunshine hours (only adults) exhibited non-significant negative correlation with the population of *H. vigintioctopunctata*. Only morning relative humidity showed significant negative correlation with larvae ($r = - 0.452$, $P = 0.05$), pupae ($r = - 0.447$, $P = 0.05$), adult ($r = - 0.510$, $P = 0.01$) and overall population (larvae + pupae + adult) of the beetle ($r = - 0.517$, $P = 0.01$).

4.5 Seasonal population trend of *H. vigintioctopunctata* on brinjal during 1999 – 2000

Data on field population trend of *H. vigintioctopunctata* (Table 9) along with the prevailing meteorological data (Appendix U) for the crop season are shown in Figure 5.

Adults and egg masses of *H. vigintioctopunctata* were seen during the seedling (S_3) stage of the crop, in the fourth week of November (25 November), registering a population of 0.23 adults and 0.20 egg masses per plant. On December 2, the population reached to a level of 0.16 egg masses, 0.30 larvae and 0.60 adults per plant. On the next sampling date (9 December) when the crop entered early vegetative (V_1) stage, the egg masses totally disappeared, while larval population increased (0.53/plant) and adult populations fell down to 0.43/plant. From there onwards, larvae and adult population further decreased to levels of 0.20/plant and 0.10/plant, respectively, in the third week of December (23 December). On this date, pupae were noticeable in the crop with a density of 0.16 pupae/plant but disappeared after one week. Larval stages disappeared one week before disappearance of pupal stage *i.e.*, on 30 December. From mid vegetative (V_2)

Table 9. Seasonal population trends of *H. vigintioctopunctata* and extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* on brinjal during 1999-2000

Sampling date	Crop growth stage	Population density of <i>H. vigintioctopunctata</i> (no./2 branches)				Extent of parasitization (%)				
		Egg	Larva	Pupa	Adult	<i>Tetrastichus</i> sp.		<i>P. foveolatus</i>		
						Egg	Larva	Larva	Pupa	
November	25	S ₁	0.20	0.00	0.00	0.23	0.00	0.00	0.00	0.00
December	2		0.16	0.30	0.00	0.60	0.00	0.00	0.00	0.00
	9	V ₁	0.00	0.53	0.00	0.43	0.00	0.00	0.00	0.00
	16		0.00	0.40	0.00	0.26	0.00	15.00	0.00	0.00
	23		0.00	0.20	0.16	0.10	0.00	0.00	0.00	0.00
	30		0.00	0.00	0.10	0.13	0.00	0.00	0.00	0.00
January	6	V ₂	0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00
	13		0.00	0.00	0.00	0.20	0.00	0.00	0.00	0.00
	20	V ₃	0.00	0.00	0.00	0.56	0.00	0.00	0.00	0.00
	27	R ₁	0.13	0.00	0.00	0.80	0.00	0.00	0.00	0.00
February	3	R ₂	0.43	0.20	0.00	0.53	7.00	0.00	0.00	0.00
	10		0.32	0.46	0.00	0.58	18.75	17.40	0.00	0.00
	17	R ₃	0.20	0.63	0.00	0.66	30.00	20.60	0.00	0.00
	24		0.48	0.95	0.00	0.83	31.25	24.20	0.00	0.00
March	2		1.36	1.80	0.66	0.92	14.70	22.20	0.00	0.00
	9	R ₄	0.64	3.42	1.08	0.69	43.75	21.34	0.00	14.80
	17		0.31	8.16	1.95	1.32	38.70	22.70	8.60	27.15
	24	R ₅	0.16	11.80	5.20	2.19	18.75	24.06	7.80	31.70
	31		0.00	2.16	3.96	2.63	0.00	0.00	18.50	17.17
April	7		0.00	0.00	1.73	2.86	0.00	0.00	0.00	17.34
	14	R ₆	0.00	0.00	0.36	0.62	0.00	0.00	0.00	8.30
	21		0.00	0.00	0.00	0.13	0.00	0.00	0.00	0.00

Mean of 30 samples

* Data represent mean population/plant upto V₁ stage, and mean population/2 branches in other stages

stage to late vegetative (V_3) stage of the crop, *i.e.*, during 6 – 20 January, only adults were seen with a density ranging from 0.13 – 0.56 adults/2branches. At the start of the reproductive (R_1) stage on 27 January, egg masses reappeared with a low population of 0.13 egg masses/2 branches. Subsequently, larvae reappeared on 3 February and pupae on 2 March. From the date of reappearance of egg, larvae and pupae, they increased gradually and ultimately reached their peaks with population densities in of 1.36/2 branches (2 March), 11.80 /2 branches (24 March) and 5.20/2 branches (24 March), respectively. Adult beetles since their first appearance, were almost always present in the crop till they attained climax at the fruit ripening (R_5) stage, in the first week of April (7 April). All the stages of the beetle after attainment of their peak populations declined and finally disappeared from the crop in the fruit ripening stage (R_5 and R_6), whereas adults still remained in the crop till the last sampling date with a population density of 0.13/2 branches.

4.5.1 Impact of natural enemies on *H. vigintioctopunctata* population during 1999 – 2000

Table 9 and Figure 5 show the extent of parasitization by *Tetrastichus* sp. and *Pediobius foveolatus* (Craw) on different densities of *H. vigintioctopunctata* population.

The parasitoid, *Tetrastichus* sp. appeared in the crop, when population of the host larvae stood at 0.80/plant in the third week of December (16 December) while the parasitoid, *P. foveolatus* initiated their activity lately with 14.80 per cent parasitization of pupae during second week of March (9 March), when the populations of host stages were at levels of 3.42 larvae and 1.08 pupae per 2 branches.

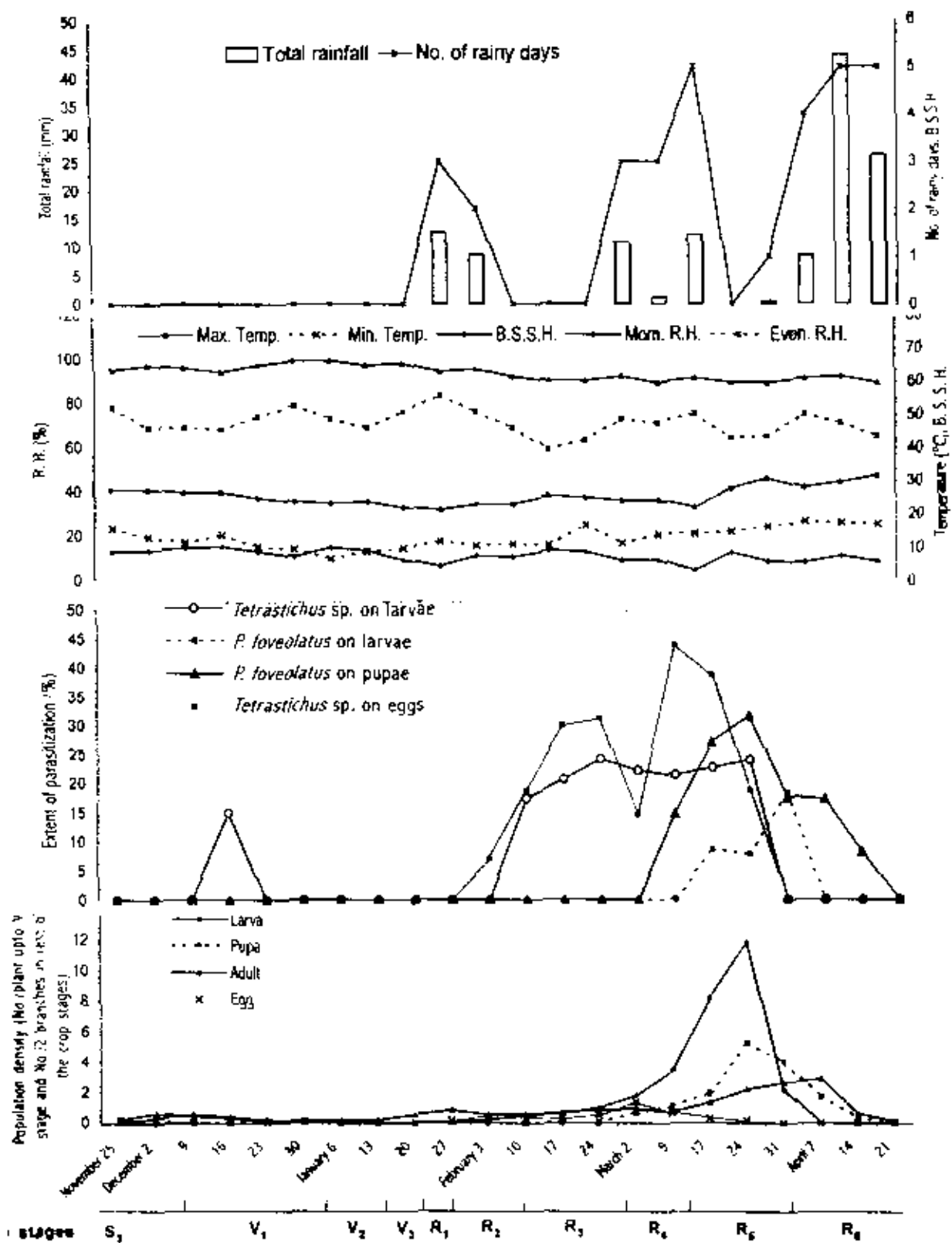


Fig. 5. Seasonal population trend of *H. vigintioctopunctata* and extent of parasitization by *Tetrastichus* sp. and *P. foveolatus* and meteorological parameters during 1999-2000

The extent of parasitization by *Tetrastichus* sp. peaked with a level of 43.75 per cent parasitization of host eggs and 24.20 per cent on early instar larvae on 9 March and 24 February, respectively. Its activity was no longer noticed in the field from the fourth week of March.

The extent of parasitization by *P. foveolatus* ranged from 7.80 – 18.50 per cent on late instar host larvae and 8.30 – 31.70 per cent on host pupae. The parasitic activity came down to zero level by 21 April.

Significant positive correlations existed between the extent of parasitization by both species and population of the prey.

Pooled correlation coefficients (r_p) for 1998 – 99 and 1999 – 2000 crop season showed that the extent of parasitization by *Tetrastichus* sp. had significant positive association with the prey population ($r = 0.618$, $P = 0.01$ for eggs and $r = 0.414$, $P = 0.05$ for larvae and $r = 0.788$, $P = 0.01$ for pupae).

4.5.2 Impact of meteorological factors on the population of *H. vigintioctopunctata* during 1999 – 2000

Correlation studies involving population of *H. vigintioctopunctata* and meteorological data (Table 10) indicated that there were positive significant correlations between minimum temperature and adult population ($r = 0.512$, $P = 0.01$). Significant negative correlations were shown by morning relative humidity with larval population ($r = -0.469$, $P = 0.05$), pupal population ($r = -0.534$, $P = 0.01$), with adult population ($r = -0.571$, $P = 0.01$) and overall beetle population ($r = -0.550$, $P = 0.01$) and bright sunshine

Table 10. Relationship of *H. vigintioctopunctata* population with meteorological factors during 1999-2000

Meteorological factors	Relationship statistics	<i>H. vigintioctopunctata</i> population during 1999-2000				
		Larva	Pupa	Adult	Egg	Larva+Pupa+Adult
Maximum temperature	r	-0.001NS	0.336NS	0.310NS	-0.293NS	0.1152NS
	100r ²	0.000	11.300	9.600	5.585	2.310
	Z	0.000	0.350	0.320	0.304	0.155
	r _p Y	0.159NS	0.301NS	0.295NS	-0.142NS	0.234NS
Minimum temperature	r	0.206NS	0.382NS	0.512**	-0.023NS	0.330NS
	100r ²	4.200	14.600	26.300	1.000	10.900
	Z	0.210	0.408	0.567	0.023	0.344
	r _p Y	0.103NS	0.173NS	0.241NS	-0.168NS	0.146NS
R.H. (Morning)	r	-0.469*	-0.534**	-0.571**	-0.322NS	-0.550**
	100r ²	22.000	28.600	32.600	10.400	30.300
	Z	0.510	0.594	0.650	0.335	0.620
	r _p Y	-0.460*	-0.485**	-0.537**	-0.284NS	-0.530**
R.H. (Evening)	r	-0.220NS	-0.260NS	-0.162NS	-0.010NS	-0.234NS
	100r ²	4.800	6.800	2.624	0.000	5.900
	Z	0.224	0.268	0.167	0.000	0.249
	r _p Y	-0.240NS	-0.254NS	-0.197NS	-0.124NS	-0.273NS
Total rain fall	r	-0.077NS	-0.068NS	-0.005NS	-0.009NS	-0.070NS
	100r ²	0.600	0.462	0.000	0.000	0.400
	Z	0.077	0.068	0.000	0.000	0.070
	r _p Y	-0.129NS	-0.149NS	-0.047NS	-0.078NS	-0.147NS
No. of rainy days	r	0.117NS	0.100NS	0.237NS	0.180NS	0.143NS
	100r ²	1.400	1.000	5.617	3.240	2.100
	Z	0.119	0.100	0.242	0.185	0.149
	r _p Y	-0.162NS	-0.173NS	0.173NS	0.190NS	-0.199NS
Bright sunshine hours	r	-0.250NS	-0.279NS	-0.438*	-0.229NS	-0.314NS
	100r ²	6.300	7.784	19.184	5.300	9.859
	Z	0.258	0.286	0.470	0.236	0.326
	r _p Y	-0.206NS	-0.121NS	-0.275NS	-0.223NS	-0.215NS
			2.123-0.181X			

NS : Not significant , * : Significant at P = 0.05, ** : Significant at P = 0.01

hours with the adult population ($r = -0.438$, $P = 0.05$). None of the other abiotic factors showed significant correlations with the population of *H. vigintioctopunctata*.

Pooled correlation coefficients (r_p) for two seasons showed negative significant relations between morning relative humidity and larval population ($r_p = -0.460$, $P = 0.05$), pupal population ($r_p = -0.485$, $P = 0.01$), adult population ($r_p = -0.537$, $P = 0.01$) and overall population of the beetle (larva + pupa + adult) ($r_p = -0.530$, $P = 0.01$).

4.6 Seasonal population indices of *H. vigintioctopunctata* on brinjal

The population of *H. vigintioctopunctata* was found to be below the seasonal average (1.24/2 branches) upto the second fortnight of January since the time it appeared in the field (Table 11 and Figure 6). Their population was more from the first fortnight of February to second fortnight of March. Similarly, the seasonal indices worked out for these fortnights were also high. The highest seasonal index of 400.00 was found for the first fortnight of March, in which population peak was recorded during 1998 – 99.

4.7 Predatory efficiency of adult coccinellids on *A. gossypii*

The predatory efficiencies of *Coccinella repanda* Thunb., *Menochilus sexmaculatus* F. and *Micraspis discolor* (F.) were studied in the laboratory. The results are shown in Table 12.

Predatory efficiencies of the coccinellids were studied by offering separately ten, twenty, thirty, forty and fifty numbers of *A. gossypii* (all stages) to the predators. The observation on feeding efficiency was recorded after 24 hours. It is evident from the table that the mean predatory efficiency on aphids was highest (84.52%), registered by

Table 11. Seasonal indices of *H. vigintioctopunctata* population on brinjal

Month	Fortnight	*Population density (no./2 branches/plant) during crop season			Seasonal Index
		1998-1999	1999-2000	Mean	
October	II	0.48	0.00	0.24	19.35
November	I	0.66	0.00	0.33	26.60
	II	0.78	0.08	0.43	34.70
December	I	0.71	0.31	0.51	41.13
	II	0.16	0.15	0.15	12.10
January	I	0.12	0.05	0.08	6.45
	II	0.37	0.23	0.30	24.20
February	I	2.35	0.29	1.32	106.45
	II	5.34	0.51	2.92	235.50
March	I	8.66	1.26	4.96	400.00
	II	3.14	4.88	4.01	323.39
April	I	0.68	0.92	0.80	64.52
	II	0.17	0.04	0.10	8.06
Mean		1.82	0.67	1.24	100.00

* No. of beetles/plant during November and December (S₃ and V₁ stage of the crop) and no. of beetles/2 branches in rest of the months

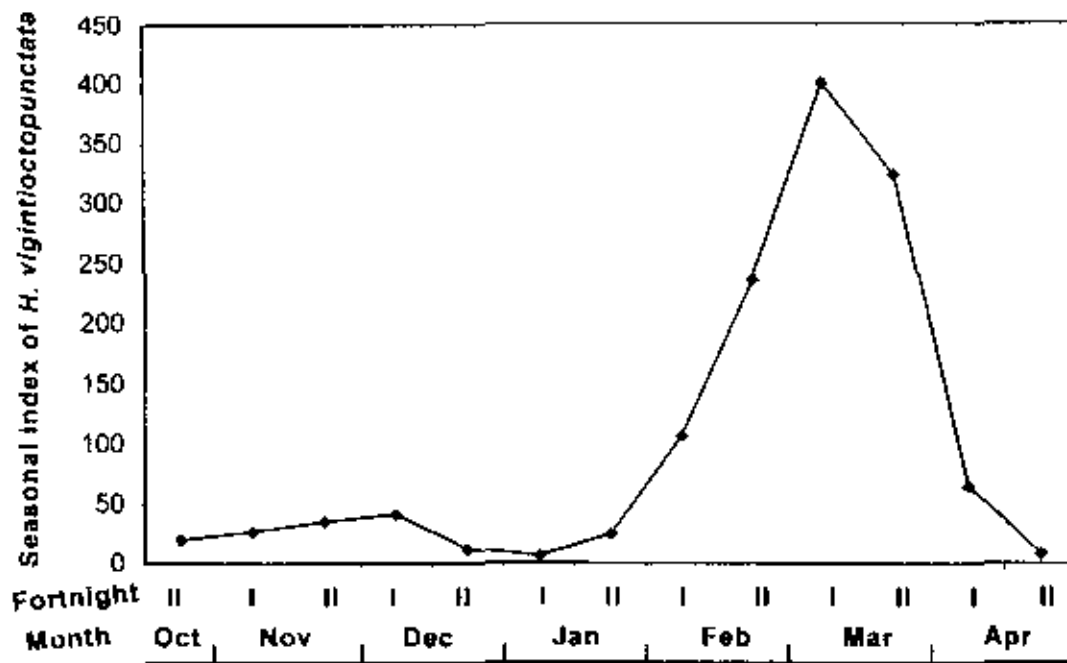


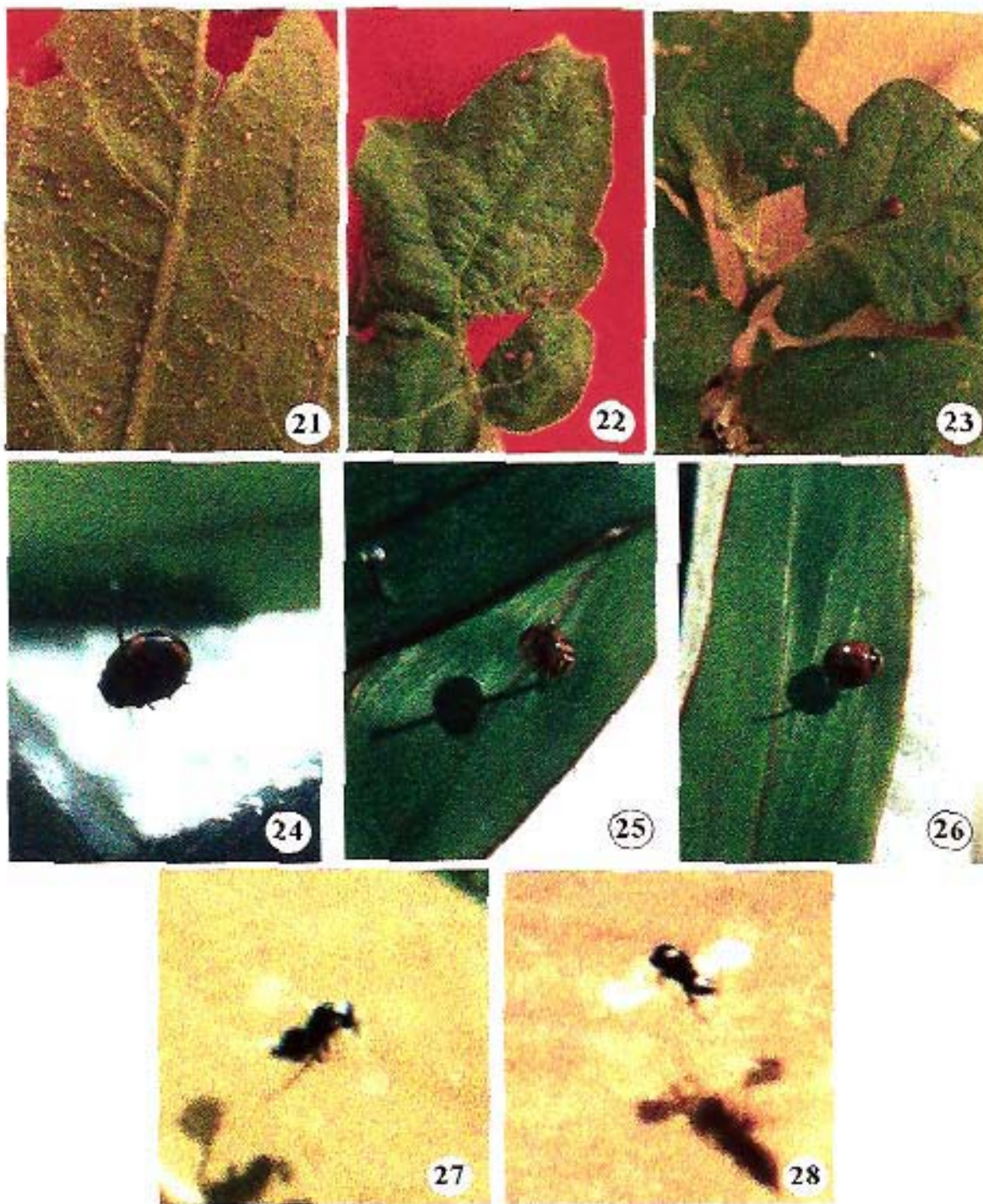
Fig. 6. Seasonal indices of *H. vigintioctopunctata* on brinjal (based on data of 1998-99, 1999-2000)

Table 12. Predatory efficiency of adult coccinellid predators

Predator	Predatory efficiency (%)					Mean
	No. of <i>A. gasypii</i> offered/24 h					
	10	20	30	40	50	
<i>C. repanda</i>	100.00 (90.00)	100.00 (90.00)	87.78 (69.54)	74.90 (59.93)	59.70 (50.59)	84.52 (52.01)
<i>M. sexmaculatus</i>	100.00 (90.00)	79.44 (63.04)	54.80 (47.75)	41.39 (40.03)	33.11 (35.12)	61.78 (55.19)
<i>M. discolor</i>	100.00 (90.00)	56.11 (48.51)	40.37 (39.44)	30.28 (33.44)	25.44 (30.29)	50.46 (48.46)
S.Ed±	NS	0.620	0.784	0.671	0.529	0.339
CD(P = 0.05)	NS	1.518	1.918	1.643	1.295	0.831
CD(P = 0.01)	NS	2.298	2.906	2.487	1.961	1.258

Data based on three replications

Figures in the parentheses are angular values



- Plate 21. A brinjal leaf infested by *A. gossypii*
 Plate 22. A brinjal leaf infested by *H. vigintioctopunctata* larvae
 Plate 23. A brinjal leaf infested by *H. vigintioctopunctata* adult
 Plate 24. An adult of *C. repanda*
 Plate 25. An adult of *M. sexmaculatus*
 Plate 26. An adult of *M. discolor*
 Plate 27. An adult of *Tetrastichus* sp.
 Plate 28. An adult of *P. foveolatus*

C. repanda and lowest (50.46%) by *M. discolor* for all levels of prey density. The results also indicated that the efficiencies of the predators were non significant when they were offered ten numbers of prey. But when the level of prey density increased to twenty, thirty, forty and fifty per adult coccinellid, the efficiency of predation significantly differed at $P < 0.01$. Highly significant difference in mean predatory efficiency indicated that *C. repanda* was the most efficient predator of *A. gossypii* followed by *M. sexmaculatus* and *M. discolor*.

4.8 Spatial distribution pattern

4.8.1 Spatial distribution pattern of *A. gossypii* nymphs on brinjal during 1998-99

The parameters related to the distribution of *A. gossypii* nymphs on brinjal are summarized in Table 13.

The nymphs of *A. gossypii* appeared in the crop during the second week of October, when the crop was at seedling (S_3) stage with a population density of 6.93 nymphs/plant in plant inspection method-1 [PI(A)-1] and 6.98 nymphs/plant in plant inspection method-2 [PI(A)-2]. The population gradually increased to attain a peak (35.13 nymphs/6 leaves) in PI(A)-1 and [51.70 nymphs/9 leaves in PI(A)-2] on 21 January during flowering (R_2) stage of the crop. Thereafter, the population started decreasing. In both the methods, the variance to mean ratios were greater than unity for nymphs, indicating clumped distribution. However, low values of ratios (<1) were also obtained by both methods during S_3 stage (14 October and 28 October), which indicated tendency towards regular distribution. The exponent 'k' ranged from -22.88 to -9.11 during the month of October and 1.70 to 32.00 during rest of the months for both the

Table 13. Parameters of spatial distribution of *A. gossypii* nymphs on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping (I_{95})	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C)	Pattern of distribution	Mean clump size (\bar{A})
S ₃	October 14	PI(A)-1	6.93	2.78	0.40	-11.56	0.24	-0.60	6.33	0.91	7.33	R	-
		PI(A)-2	6.98	3.61	0.51	-14.45	0.27	-0.49	6.49	0.92	7.49	R	-
V ₁	October 28	PI(A)-1	6.60	1.82	0.27	-9.11	0.20	-0.73	5.87	0.89	6.87	R	-
		PI(A)-2	9.14	5.49	0.60	-22.88	0.26	-0.40	8.74	0.96	9.74	R	-
V ₁	November 11	PI(A)-1	9.47	14.69	1.55	17.18	0.40	0.51	10.02	1.06	11.02	C	13.47
		PI(A)-2	13.66	28.29	2.07	12.75	0.39	1.07	14.73	1.08	15.73	C	20.49
V ₂	November 25	PI(A)-1	4.80	6.31	1.31	15.26	0.52	0.31	5.11	1.06	6.11	C	26.62
		PI(A)-2	6.38	11.52	1.80	7.91	0.53	0.80	7.18	1.12	8.18	C	10.51
V ₂	December 9	PI(A)-1	8.33	17.66	2.11	7.44	0.50	1.11	9.44	1.13	10.44	C	13.89
		PI(A)-2	11.26	28.92	2.56	7.18	0.48	1.56	12.82	1.14	13.82	C	18.96
V ₃	December 23	PI(A)-1	3.81	5.89	1.54	6.97	0.64	0.54	4.35	1.14	5.35	C	6.45
		PI(A)-2	5.21	14.75	2.83	2.84	0.74	1.83	7.04	1.35	8.04	C	11.09
R ₁	January 7	PI(A)-1	14.40	40.25	2.79	8.02	0.44	1.79	16.19	1.12	17.19	C	23.99
		PI(A)-2	24.60	62.17	2.53	16.10	0.32	1.53	26.13	1.06	27.13	C	35.49
R ₂	January 21	PI(A)-1	35.13	73.69	1.81	32.00	0.24	0.81	35.94	1.02	36.94	C	46.02
		PI(A)-2	51.70	204.90	3.96	17.45	0.28	2.96	54.66	1.06	55.66	C	73.72
R ₃	February 4	PI(A)-1	23.93	59.35	2.48	16.17	0.32	1.48	25.41	1.06	26.41	C	34.50
		PI(A)-2	27.30	97.30	3.56	10.65	0.36	2.56	29.86	1.09	30.86	C	42.35
R ₄	February 18	PI(A)-1	5.40	10.40	1.93	5.83	0.60	0.93	6.33	1.17	7.33	C	9.51
		PI(A)-2	9.70	22.90	2.36	7.13	0.49	1.36	11.06	1.14	12.06	C	16.36
R ₅	March 4	PI(A)-1	5.80	22.69	3.91	1.99	0.82	2.91	8.71	1.50	9.71	C	13.75
		PI(A)-2	8.10	24.98	3.08	3.89	0.62	2.08	10.18	1.26	11.18	C	15.80
R ₅	March 18	PI(A)-1	7.40	15.68	2.12	6.61	0.53	1.12	8.52	1.15	9.52	C	12.68
		PI(A)-2	13.70	45.78	3.34	5.85	0.49	2.34	16.04	1.17	17.04	C	24.14
R ₆	April 1	PI(A)-1	1.00	1.28	1.28	3.57	1.13	0.28	1.28	1.28	2.28	C	2.00
		PI(A)-2	4.30	7.78	1.81	5.32	0.65	0.81	5.11	1.19	6.11	C	7.76
R ₆	April 16	PI(A)-1	1.53	2.69	1.76	2.02	1.07	0.76	2.29	1.49	3.29	C	3.62
		PI(A)-2	1.10	1.81	1.64	1.70	1.22	0.64	1.74	1.58	2.74	C	2.72

C = Clumped; R = Regular; No. of samples (N) drawn: in PI(A)-1 = 15; in PI(A)-2 = 10

sampling methods. There were 15 cases where 'k' values were less than eight which was indicative of high amount of clumping and in nine other cases, k was greater than eight which signified low clumping. There were positive indices of clumping in all the sampling dates and methods except for 14 October and 28 October in both the methods, which indicated aggregated distribution of nymphs. The results of mean crowding, Lloyd's patchiness index and mean colony size confirmed the contagious nature of distribution. Mean clump size computed for the nymphal population showed that the values were greater than two for most of the cases which signified that the clumping was due to both environmental heterogeneity as well as intrinsic behaviour of *A. gossypii* nymphs. However, at fruit ripening (R_6) stage (1 April) the clumping was due to micro environmental heterogeneity when sampled by PI(A)-1, as the mean clump size was exactly two.

Iwao's patchiness regression for PI(A)-1 and PI(A)-2 methods were $X^* = 0.616 + 1.020\bar{X}$ (Figure 7A) and $X^* = 0.659 + 1.049\bar{X}$ (Figure 7B) respectively, which revealed that there was a positive association among nymphs. The indices of basic contagion suggested that the nymphs had a tendency of colony formation. As the density contagiousness co-efficients (1.020 and 1.049) were greater than unity, the nymphs were over-dispersed in the brinjal crop. The co-efficients of determination (R^2) were 99.1 and 99.7 per cent under PI(A)-1 and PI(A)-2, respectively, (Table 14). Significance of F tests confirmed good fitness of these models.

Table 14. Taylor's power law and Iwao's patchiness regression parameters for spatial distribution of nymph and adult *A. gossypii* during 1998-99 and 1999-2000

Crop season	Sampling method	Taylor's Power law															
		<i>A. gossypii</i> nymphs					<i>A. gossypii</i> adults					<i>A. gossypii</i> alate adults					
		a	b	R ²	Statistic F	a	b	R ²	Statistic F	a	b	R ²	Statistic F	a	b	R ²	Statistic F
1998-99	PI(A)-1	0.067	1.144 ^c	0.700	27.98**	-0.032	1.323 ^c	0.713	29.81**	0.186	1.197 ^c	0.974	62.64**				
	PI(A)-2	0.051	1.263 ^c	0.815	52.84**	0.189	1.084 ^c	0.754	36.74**	0.185	1.206 ^c	0.986	65.35**				
1999-2000	PI(A)-1	0.191	1.804 ^c	0.885	76.75**	0.131	1.329 ^c	0.591	14.43**	0.079	1.075 ^c	0.891	52.21**				
	PI(A)-2	0.068	1.912 ^c	0.821	45.84**	0.153	1.508 ^c	0.714	25.02**	0.102	1.269 ^c	0.865	27.25**				
Iwao's patchiness regression																	
		α	β	R ²	Statistic F	α	β	R ²	Statistic F	α	β	R ²	Statistic F	α	β	R ²	Statistic F
1998-99	PI(A)-1	0.616	1.020 ^c	0.991	1327.73**	0.358	1.024 ^c	0.986	820.07**	0.095	1.516 ^c	0.922	28.19**				
	PI(A)-2	0.659	1.049 ^c	0.997	3622.6**	0.982	0.989 ^a	0.969	376.52**	0.081	1.486 ^c	0.939	30.68**				
1999-2000	PI(A)-1	0.790	1.871 ^c	0.751	30.10**	0.356	1.320 ^c	0.338	5.10*	-0.025	1.433 ^c	0.946	27.88**				
	PI(A)-2	0.989	1.874 ^c	0.641	17.84**	-1.366	2.390 ^c	0.727	29.34**	-0.062	1.539 ^c	0.958	25.39**				

* Significant at P = 0.05

** Significant at P = 0.01

^c Clumped

R Regular

The regression based on Taylor's power law for the nymphs of *A. gossypii* were $\log S^2 = 0.067 + 1.144 \log \bar{X}$ in PI(A)-1 and $\log S^2 = 0.051 + 1.263 \log \bar{X}$ in PI(A)-2, shown in Figure 8A and 8B, respectively.

Index of aggregation values of these models were found to be more than one, which signifies the aggregated distribution of the nymphs. R^2 values shown in Table 14 confirmed that there were 70.00 per cent of data of PI(A)-1 methods and 81.50 per cent of data of PI(A)-2 methods fitted to the linear regression models based on Taylor's power law.

4.8.2 Spatial distribution pattern of *A. gossypii* adults on brinjal during 1998-1999

Data presented in Table 15 and 16 represents the different statistical parameters for spatial distribution of *A. gossypii* adults of both apterae and alatae.

The adults of *A. gossypii* appeared in the crop during second week of October with a density of 3.67 apterae and 0.40 alatae per plant in PI(A)-1 and 4.56 apterae and 0.37 alatae per plant in PI(A)-2 method when the crop was in seedling (S_3) stage. The apterous adult population rose to peak in R_2 stage (flowering) in the third week of January [17.13 adults/6 leaves in PI(A) - 1 and 16.30 adults/9 leaves in PI(A) - 2]. Alate adults on the other hand, peaked during first week of April [1.86 adults/6 leaves in PI(A)-1 and 2.08 adults/9 leaves in PI(A)-2] at the declining stage (R_4) of the crop. From there onwards, the adult population showed a declining trend. In all the methods of sampling, the variance to mean ratio exceeded unity in almost all the occasions, which indicated contagious nature of distribution for both apterous and alate adults. The values of exponent-k for majority of the samples were less than eight which indicated that a high

Table 15. Parameters of spatial distribution of *A. gossypii* adults on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping (I_{DM})	Mean crowding index (X')	Lloyd's patchiness index (X'/\bar{X})	Mean colony size (C')	Pattern of distribution	Mean clump size (λ)
S ₃	October 14	PI(A)-1	3.67	1.95	0.53	-7.84	0.38	-0.47	3.20	0.87	4.20	R	-
		PI(A)-2	4.56	6.13	1.34	13.24	0.54	0.34	4.90	1.07	5.90	C	6.80
	October 28	PI(A)-1	2.93	1.64	0.56	-6.67	0.44	-0.44	2.49	0.84	3.49	R	-
		PI(A)-2	3.28	4.35	1.33	10.05	0.63	0.33	3.61	1.10	4.61	C	5.15
V ₁	November 11	PI(A)-1	3.80	4.60	1.21	18.05	0.42	0.21	4.01	1.05	5.01	C	5.39
		PI(A)-2	7.43	11.36	1.53	14.04	0.45	0.53	7.96	1.07	8.96	C	10.96
	November 25	PI(A)-1	3.20	6.74	2.11	2.89	0.81	1.11	3.31	1.03	4.31	C	6.78
		PI(A)-2	4.21	8.43	2.00	4.19	0.69	1.00	5.21	1.24	6.21	C	10.66
V ₂	December 9	PI(A)-1	3.80	6.60	1.74	5.16	0.68	0.74	4.54	1.19	5.54	C	6.88
		PI(A)-2	4.70	15.67	3.33	2.01	0.84	2.33	7.03	1.49	8.03	C	11.15
V ₃	December 23	PI(A)-1	4.67	8.09	1.73	6.40	0.61	0.73	5.40	1.16	6.40	C	8.06
		PI(A)-2	5.87	10.82	1.84	6.96	0.56	0.84	6.71	1.14	7.71	C	9.94
R ₁	January 7	PI(A)-1	5.26	14.49	2.75	2.99	0.72	1.75	6.01	1.14	7.01	C	11.09
		PI(A)-2	5.20	6.17	1.19	27.88	0.48	0.19	5.39	1.04	6.39	C	6.92
R ₂	January 21	PI(A)-1	17.13	35.83	1.51	15.69	0.35	0.51	17.64	1.03	18.64	C	24.71
		PI(A)-2	16.30	25.56	1.57	28.69	0.31	0.57	16.87	1.03	17.87	C	21.60
R ₃	February 4	PI(A)-1	10.06	19.06	1.89	11.24	0.43	0.89	10.95	1.08	11.95	C	15.44
		PI(A)-2	12.10	21.21	1.75	16.07	0.38	0.75	12.85	1.06	13.85	C	17.50
	February 18	PI(A)-1	8.73	12.78	1.46	18.81	0.41	0.46	9.19	1.05	10.19	C	15.06
		PI(A)-2	9.80	21.06	2.15	8.53	0.47	1.15	10.95	1.12	11.95	C	15.90
R ₄	March 4	PI(A)-1	3.40	6.97	2.05	3.24	0.78	1.05	4.45	1.31	5.45	C	6.97
		PI(A)-2	5.60	17.38	3.10	2.66	0.74	2.10	7.70	1.37	8.70	C	12.18
R ₅	March 18	PI(A)-1	5.33	11.09	2.08	4.93	0.62	1.08	6.41	1.20	7.41	C	9.78
		PI(A)-2	7.50	11.38	1.52	14.50	0.45	0.52	8.02	1.07	9.02	C	11.00
R ₆	April 1	PI(A)-1	3.53	6.98	1.97	3.61	0.75	0.97	4.50	1.27	5.50	C	7.03
		PI(A)-2	6.50	16.50	2.54	4.22	0.62	1.54	8.04	1.24	9.04	C	12.40
	April 16	PI(A)-1	2.53	3.38	1.33	7.53	0.73	0.33	2.86	1.13	3.86	C	4.21
		PI(A)-2	2.00	2.92	1.46	6.72	0.85	0.46	2.46	1.21	3.46	C	3.75

C = Clumped; R = Regular; No. of samples (N) drawn : in PI(A)-1 = 15; in PI(A)-2 = 10

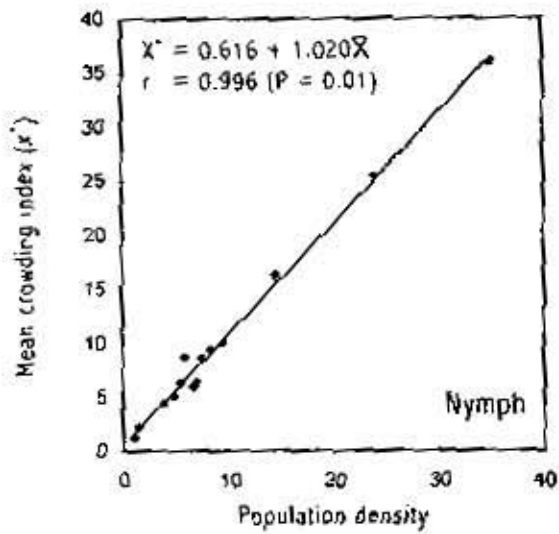


Fig. 7A

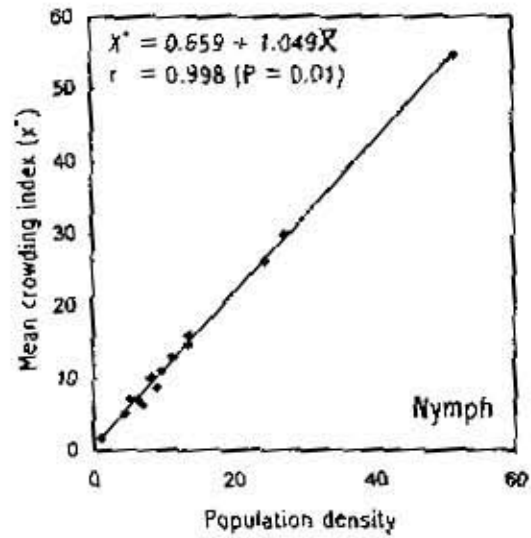


Fig. 7B

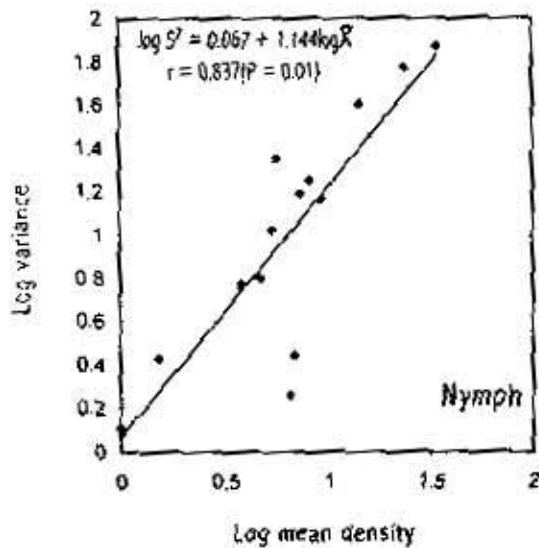


Fig. 8A

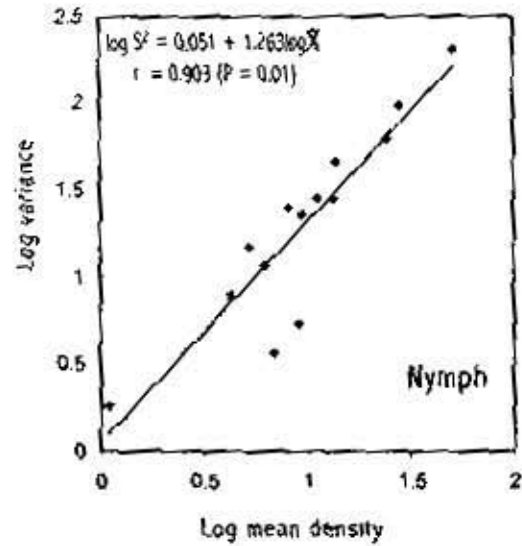


Fig. 8B

Fig. 7. Iwao's patchiness regressions of *A. gossypii* nymphs (A, B) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1998-99

Fig. 8. Taylor's power law regressions of *A. gossypii* nymphs (A, B) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1998-99

degree of contagiousness among adult populations. Larger 'k' values (>8) in few sampling occasions in case of apterous adults signified that there was a low level of clumping. It means that some population of adult apterae had a tendency towards randomness at higher density of population. The clumped nature of the adult population could also be described by the positive values of clumping index, higher mean crowding index than mean population density and Lloyd's patchiness index greater than unity in all the sampling occasion except on 14 and 28 October. The values of mean clump size for the season were greater than two in case of apterous adults, which revealed that the aggregation was due to both environmental heterogeneity the crop field as well as intrinsic behavior of *A. gossypii* adults. However, this values (< 2) for half of the cases in alate described that clumping was also due to micro-environmental heterogeneity.

Iwao's patchiness regression suggested that there was a positive association among apterous adults in $PI(A)-1$ ($X^* = 0.358 + 1.024\bar{X}$), and $PI(A)-2$ ($X^* = 0.982 + 0.989\bar{X}$) and, alate adults in $PI(A) - 1$ ($X^* = 0.095 + 1.516\bar{X}$) and $PI(A) - 2$ ($X^* = 0.081 + 1.486\bar{X}$) which are shown in Figure 9A and 9B (apterae) and Figure 9C and 9D (alatae).

The indices of basic contagion [0.358 and 0.095 in $PI(A)-1$ and 0.982 and 0.081 in $PI(A)-2$] were greater than zero, and this indicated that more than one individual formed the component of basic contagion. The density contagiousness co-efficients were greater than unity in all sampling methods except $PI(A)-2$ (apterous adult). This indicated that the colonies would tend to over-disperse in an aggregated pattern, while smaller coefficient (< 1) indicated that the colonies were not over-dispersed. The models

Table 16. Parameters of spatial distribution of *A. gossypii* alate adults on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping ($I_{(m)}$)	Mean crowding index (\bar{X})	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C')	Pattern of distribution	Mean clump size (λ)
S ₁	October 14	PI(A)-1	0.40	0.31	0.77	-1.778	1.392	-0.23	0.17	0.42	1.17	R	-
		PI(A)-2	0.37	0.34	0.92	-4.563	1.576	-0.08	0.29	0.78	1.29	R	-
V ₁	October 28	PI(A)-1	0.26	0.36	1.38	0.676	2.307	0.38	0.64	2.46	1.64	C	0.86
		PI(A)-2	0.28	0.32	1.14	1.960	2.020	0.14	0.42	1.50	1.42	C	0.68
V ₁	November 11	PI(A)-1	0.33	0.42	1.27	1.210	1.964	0.27	0.60	1.82	1.60	C	0.92
		PI(A)-2	0.35	0.38	1.08	4.083	1.761	0.08	0.43	1.23	1.43	C	0.68
V ₁	November 25	PI(A)-1	0.13	0.16	1.23	0.563	3.076	0.23	0.36	2.77	1.36	C	0.47
		PI(A)-2	0.10	0.12	1.20	0.500	3.464	0.20	0.30	3.00	1.30	C	0.38
V ₁	December 9	PI(A)-1	0.20	0.24	1.20	1.000	2.449	0.20	0.40	2.00	1.40	C	0.60
		PI(A)-2	0.23	0.29	1.26	0.881	2.341	0.26	0.49	2.13	1.49	C	0.72
V ₁	December 23	PI(A)-1	0.93	1.32	1.42	2.402	1.235	0.42	1.35	1.45	2.35	C	2.08
		PI(A)-2	0.98	1.76	1.79	1.231	1.354	0.79	1.77	1.81	2.77	C	2.75
R ₁	January 7	PI(A)-1	0.67	1.21	1.80	0.831	1.642	0.80	1.47	2.19	2.47	C	2.07
		PI(A)-2	0.72	1.30	1.80	0.894	1.583	0.80	1.52	2.11	2.52	C	2.25
R ₂	January 21	PI(A)-1	0.67	1.18	1.76	0.880	1.621	0.76	1.43	2.13	2.43	C	2.12
		PI(A)-2	0.63	1.16	1.84	0.749	1.709	0.84	1.47	2.33	2.47	C	2.07
R ₃	February 4	PI(A)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(A)-2	-	-	-	-	-	-	-	-	-	-	-
R ₄	February 18	PI(A)-1	0.40	0.43	1.07	5.333	1.639	0.07	0.47	1.17	1.47	C	0.72
		PI(A)-2	0.51	0.59	1.16	3.251	1.506	0.16	0.62	1.31	1.67	C	1.04
R ₄	March 4	PI(A)-1	0.53	0.73	1.38	1.404	1.612	0.38	0.91	1.72	1.91	C	1.41
		PI(A)-2	0.72	0.91	1.26	2.728	1.325	0.26	0.98	1.36	1.98	C	1.56
R ₅	March 18	PI(A)-1	1.00	1.86	1.86	1.163	1.364	0.86	1.86	1.86	1.86	C	2.81
		PI(A)-2	1.28	2.32	1.81	1.575	1.189	0.81	2.09	1.63	3.09	C	3.24
R ₆	April 1	PI(A)-1	1.86	3.53	1.90	2.072	1.010	0.90	2.76	1.48	3.76	C	4.33
		PI(A)-2	2.08	4.09	1.96	2.152	0.972	0.96	3.04	1.46	4.04	C	4.81
R ₆	April 16	PI(A)-1	1.46	2.66	1.82	1.776	1.117	0.82	2.28	1.56	3.28	C	3.55
		PI(A)-2	1.64	2.85	1.73	2.223	1.029	0.73	2.37	1.44	3.37	C	3.73

C = Clumped; R = Regular; No. of samples (N) drawn : in PI(A)-1 = 15; in PI(A)-2 = 10; - indicates no alate adult available

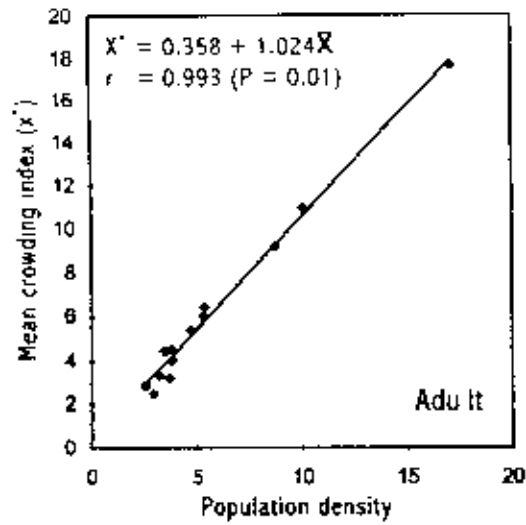


Fig. 9A

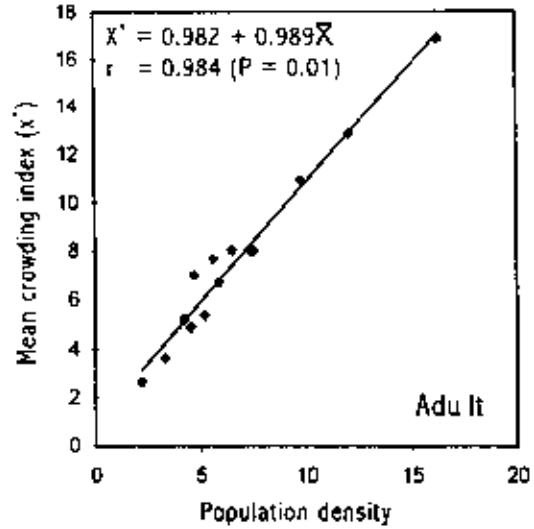


Fig. 9B

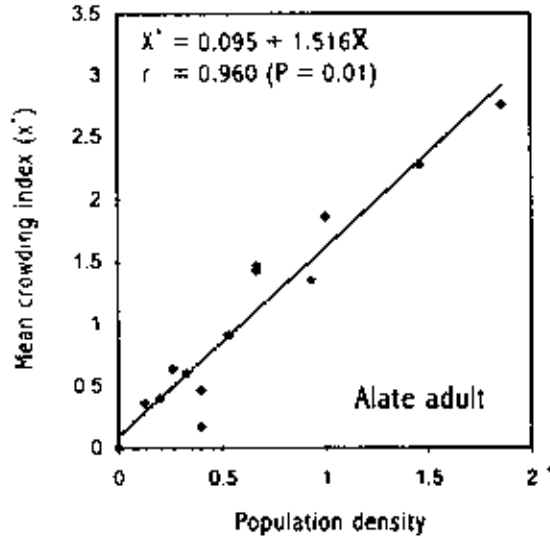


Fig. 9C

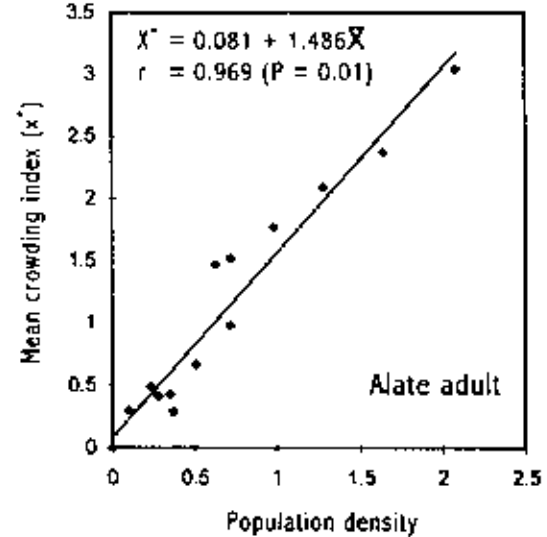


Fig. 9D

Fig. 9. Iwao's patchiness regressions of *A. gossypii* apterous adults (A, B) and alate adults (C, D) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1998-99

explained 92.2 to 98.6 per cent variation in adult dispersion in all cases as confirmed by significant higher values of R^2 (Table 14) at $P=0.01$, assured good fitness of these models.

Regression based on Taylor's power law were $\log S^2 = -0.032 + 1.323 \log \bar{X}$ in PI(A) - 1 (Figure 10A) and $\log S^2 = 0.189 + 1.084 \log \bar{X}$ in PI (A) - 2 (Figure 10B) for apterous adults and $\log S^2 = 0.186 + 1.197 \bar{X}$ in PI(A) - 1 (Figure 10C) and $\log S^2 = 0.185 + 1.206 \bar{X}$ in PI (A) - 2 (Figure 10D) for alate adults. This suggested that the distribution of adults in both sampling methods was approaching contagiousness. The values of R^2 as shown in Table 14 confirmed that 71.3 to 98.6 per cent variation in adult dispersion could be explained by the Taylor's power law model and the significance of F values (Table 14) at $P = 0.01$ further confirmed that the model showed good fitness in both the sampling methods.

4.8.3 Spatial distribution pattern of *A. gossypii* nymphs on brinjal during 1999 - 2000

The statistical parameters related to the spatial distribution of *A. gossypii* nymphs on brinjal are presented in Table 17.

On the first day of sampling (11 November) nymphal population was 2.73/plant in PI(A) - 1 and 3.12/plant in PI(A)- 2, when the crop was at S_3 stage. The population attained the peak [8.53 nymphs/6 leaves in PI(A) - 1 and 9.50 nymphs/9 leaves in PI(A)

2] during flowering (R_3) stage of the crop on 18 February. Thereafter, the nymphal population followed a declining trend. The variance to mean ratios for the nymphs were invariably more than unity on all the sampling occasions, signifying clumped

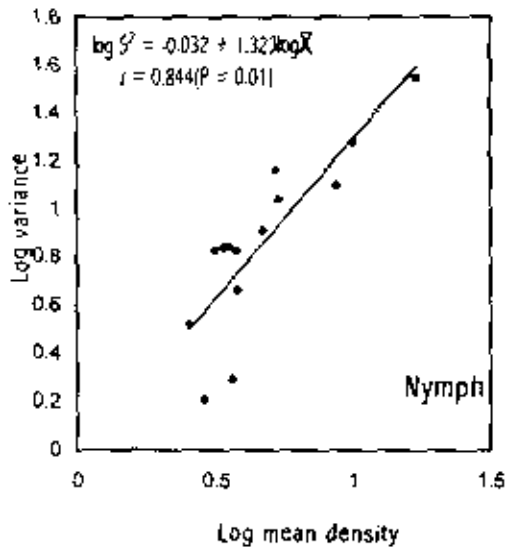


Fig. 10A

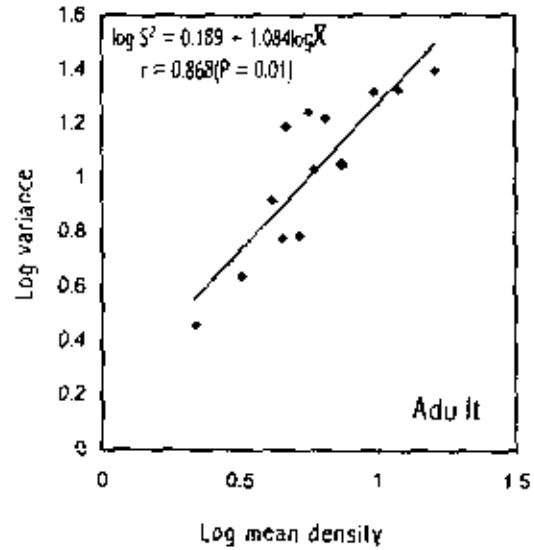


Fig. 10B

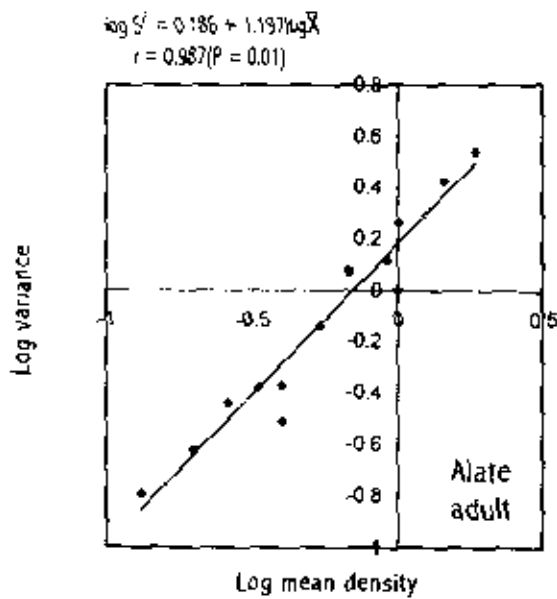


Fig. 10C

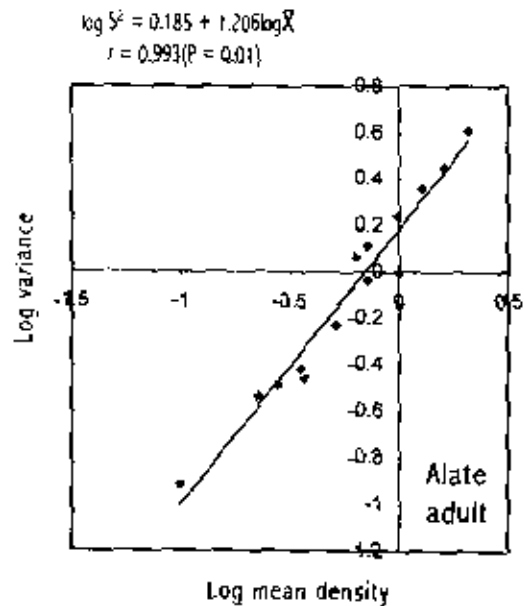


Fig. 10D

Fig. 10. Taylor's power law regressions of *A. gossypii* apterous adults (A, B) and alate adults (C, D) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1998-99

distribution. The values of dispersion parameter (k) were found to be less than eight in all the sampling dates, which clearly suggested high amount of aggregation. Simultaneously, values of David and Moore's index of clumping, mean crowding index, Lloyd's patchiness index and mean colony size also exhibited the aggregative nature of distribution of the nymphal population. The values of mean clump size were found to be greater than two during the season except one observation which justified that the causes of aggregation are environmental effect and the active behaviour of *A. gossypii* nymphs.

Iwao's patchiness regressions were worked out as $X^* = 0.790 + 1.871\bar{X}$ in PI(A) - 1 and $X^* = 0.989 + 1.874\bar{X}$ in PI(A) - 2 (Table 14) and these are graphically presented in Figure 11A and Figure 11B, respectively.

The indices of basic contagion (> 0) and density contagiousness coefficients (> 1) found in these two models explained that the distribution was contagious. Per cent coefficient of determination (64.10 to 75.10 per cent) with significant F values ($P = 0.01$) (Table 14) indicated good fit of these models with the sampling methods.

Regressions based on Taylor's power law were $\log S^2 = 0.191 + 1.804 \log \bar{X}$ in PI(A) - 1 (Figure 12A) and $\log S^2 = 0.068 + 1.912\bar{X}$ in PI(A) - 2 (Figure 12B) and the values are tabulated in Table 14.

The indices of aggregation were found to be greater than unity in all the sampling methods. R^2 ranged from 0.821 to 0.885 in all the sampling methods which was an indication that 82.10 to 88.50 per cent of variation in distribution of nymphal population could be explained by the Taylor's power law models. However, good fitness of the

Table 17. Parameters of spatial distribution of *A. gossypii* nymphs on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping (I_{low})	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (\bar{C})	Pattern of distribution	Mean clump size (\bar{k})
S ₁	November 11	PI(A)-1	2.73	5.49	2.01	2.699	0.858	1.01	3.74	1.37	4.74	C	5.05
		PI(A)-2	3.12	9.74	3.12	0.675	1.000	2.12	5.24	1.68	6.24	C	10.68
	November 25	PI(A)-1	8.00	35.60	4.45	2.318	0.746	3.45	11.65	3.43	12.45	C	18.09
		PI(A)-2	8.15	32.63	4.00	2.712	0.701	3.00	11.15	1.37	12.15	C	17.56
V ₁	December 9	PI(A)-1	5.93	38.35	6.47	1.084	1.044	5.47	11.40	1.92	12.40	C	17.14
		PI(A)-2	6.14	56.58	9.21	0.747	1.225	8.21	14.35	2.34	15.35	C	20.12
	December 23	PI(A)-1	1.93	4.06	2.10	1.746	1.044	1.10	3.03	1.57	4.03	C	4.76
		PI(A)-2	2.88	5.11	1.77	3.717	0.764	0.77	3.65	1.27	4.65	C	5.69
V ₂	January 6	PI(A)-1	0.66	1.02	1.54	1.210	1.530	0.54	1.20	1.82	2.20	C	1.85
		PI(A)-2	2.00	1.77	3.88	0.693	1.393	2.88	4.88	2.44	5.88	C	6.71
	January 20	PI(A)-1	2.86	7.69	2.69	1.693	0.969	1.69	4.55	1.59	5.55	C	7.13
		PI(A)-2	3.00	6.44	2.15	2.616	0.846	1.15	4.15	1.38	5.15	C	6.56
R ₂	February 3	PI(A)-1	4.53	37.83	8.35	0.616	1.358	7.35	11.88	2.62	12.88	C	15.70
		PI(A)-2	7.00	93.77	13.39	0.564	1.383	12.39	19.39	2.77	20.39	C	25.81
	February 18	PI(A)-1	8.53	82.40	9.66	0.984	1.064	8.66	17.19	2.01	18.19	C	26.06
		PI(A)-2	9.50	170.72	17.97	0.559	1.375	16.97	26.47	2.79	27.47	C	35.03
R ₄	March 2	PI(A)-1	2.53	15.40	6.08	0.500	1.551	5.08	7.61	3.00	8.61	C	9.72
		PI(A)-2	3.80	22.84	6.01	0.758	1.258	5.01	8.81	2.32	9.81	C	12.37
	March 17	PI(A)-1	1.53	1.98	1.29	5.200	0.919	0.29	1.92	1.25	2.92	C	2.77
		PI(A)-2	3.10	6.76	2.18	0.623	0.838	1.18	4.28	1.38	5.28	C	6.78
R ₅	March 31	PI(A)-1	1.53	6.12	4.00	0.510	1.616	3.00	4.53	2.96	5.53	C	5.76
		PI(A)-2	3.40	13.60	4.00	1.133	1.084	3.00	6.40	1.88	7.40	C	9.67

C = Clumped; No. of samples (N) drawn : in PI(A)-1 = 15; in PI(A)-2 = 10

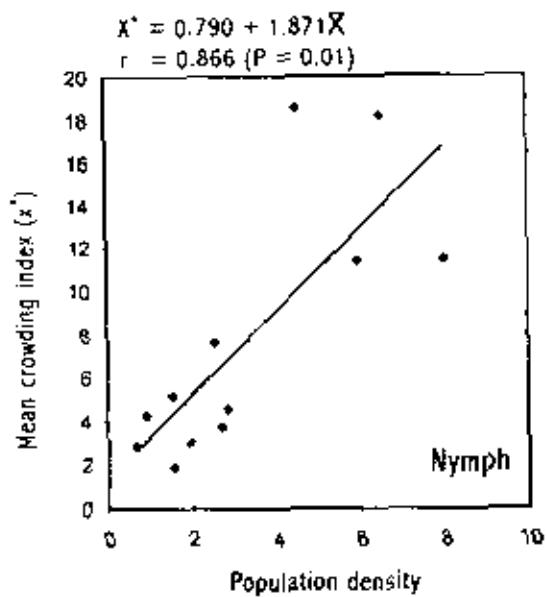


Fig. 11A

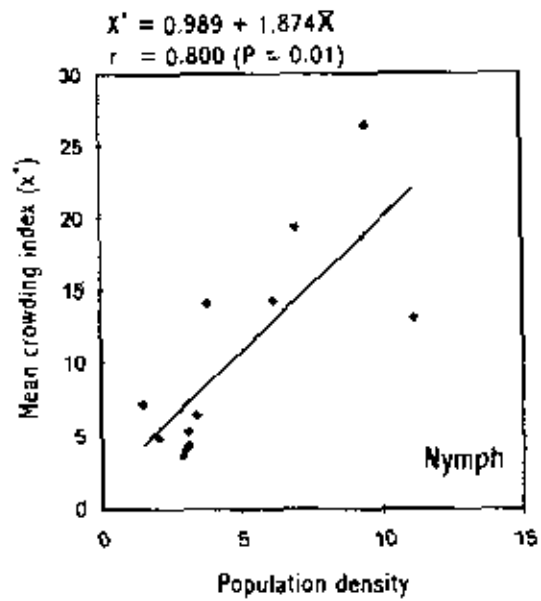


Fig. 11B

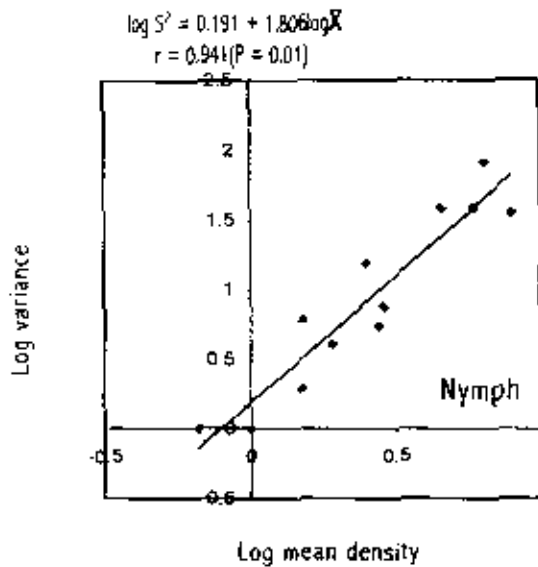


Fig. 12A

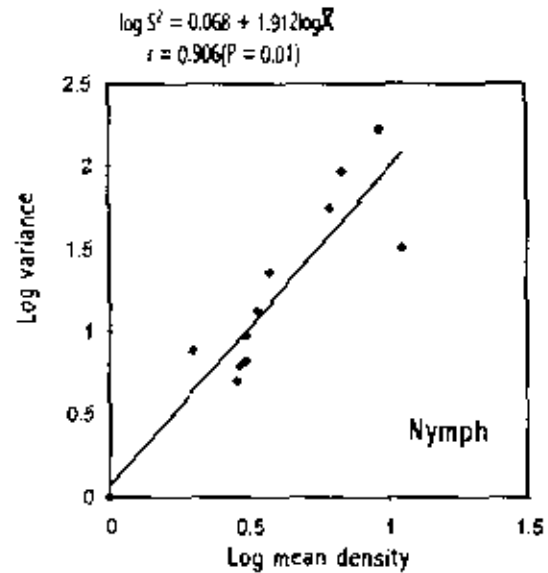


Fig. 12B

Fig. 11. Iwao's patchiness regressions of *A. gossypii* nymphs (A, B) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1999-2000

Fig. 12. Taylor's power law regressions of *A. gossypii* nymphs (A, B) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1999-2000

model was confirmed by significant F values (Table 14) at $p = 0.01$ in all the sampling methods.

4.8.4 Spatial distribution pattern of *A. gossypii* adults on brinjal during 1999 – 2000

Statistical parameters describing the nature of dispersion of *A. gossypii* adults are presented in Table 18 and 19.

The adults of *A. gossypii* appeared in the brinjal field during the second week of November at the seedling (S_3) stage of the crop. The peak population density of the apterous adults were attained at a level of 2.26 adults/6 leaves in PI (A) – 1 on 2 March and 3.60 adults/9 leaves in PI (A) – 2 on 18 February at fruit initiation (R_3) stage of the crop. A late adults on the other hand, reached their peak on 14 April [1.46 adults/6 leaves in PI(A) – 1 and 1.65 adults/9 leaves in PI(A) – 2] when the crop was in declining stage. The values of variance to mean ratio over one were an indicative of clumped distribution in almost all the sampling dates except one or two occasions during November. In none of the sampling dates, the values of 'k' were found greater than eight, signifying high degree of clumping in the case of both apterous adults and alate adults. Similar types of distribution were also explained by the David and Moore's index of clumping, mean crowding index, Lloyd's patchiness index and mean colony size. The values of mean clump size were greater than two in 16 cases out of 20 cases for apterous population and 7 cases out of 14 for alate adults, which revealed that the clumping of adults was mainly due to environmental variation in the crop field as well as behaviour of the adults. These values less than two in the case of alatae suggested that clumping was also due to micro-environmental heterogeneity.

Table 18. Parameters of spatial distribution of *A. gossypii* adults on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping (low)	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C)	Pattern of distribution	Mean clump size (A)
S ₁	November 11	PI(A)-1	1.20	1.00	0.83	-7.200	0.833	-0.17	1.03	0.86	2.03	R	-
		PI(A)-2	1.67	1.40	0.84	-10.333	0.708	-0.17	1.50	0.90	2.50	R	-
V ₁	November 25	PI(A)-1	1.73	0.63	0.36	-2.720	0.458	-0.64	1.09	0.63	2.09	R	-
		PI(A)-2	2.23	1.66	0.74	-8.720	0.577	-0.26	1.97	0.88	2.97	R	-
V ₂	December 9	PI(A)-1	1.71	7.91	4.62	0.500	1.644	3.62	5.33	3.12	6.33	C	6.57
		PI(A)-2	2.12	10.36	4.89	0.545	1.518	3.89	6.01	2.83	7.01	C	8.14
V ₃	December 23	PI(A)-1	1.26	1.49	1.18	6.913	0.968	0.18	1.44	1.14	2.44	C	2.14
		PI(A)-2	1.72	2.13	1.24	7.219	0.848	0.24	1.96	1.13	2.96	C	2.89
R ₁	January 6	PI(A)-1	0.53	0.69	1.30	1.750	1.567	0.30	0.83	1.57	1.83	C	1.30
		PI(A)-2	0.90	1.21	1.34	2.612	1.222	0.34	1.24	1.38	2.24	C	1.97
R ₂	January 20	PI(A)-1	0.93	1.48	1.59	1.563	1.308	0.59	1.52	1.63	2.52	C	2.39
		PI(A)-2	1.40	1.93	1.37	3.698	0.992	0.37	1.77	1.26	2.77	C	2.77
R ₃	February 3	PI(A)-1	1.33	3.66	2.75	0.759	1.438	1.75	3.08	2.31	4.08	C	4.36
		PI(A)-2	3.30	9.56	2.90	1.739	0.936	1.90	5.20	1.57	6.20	C	8.15
R ₄	February 18	PI(A)-1	2.13	3.55	1.67	3.190	0.884	0.67	2.80	1.31	3.80	C	4.38
		PI(A)-2	3.60	25.37	7.05	0.595	1.399	6.05	9.65	2.68	10.65	C	12.81
R ₅	March 2	PI(A)-1	2.26	5.06	2.24	1.821	0.995	1.24	3.50	1.55	4.50	C	5.53
		PI(A)-2	3.20	15.06	4.70	0.863	1.212	3.70	6.90	2.16	7.90	C	10.06
R ₆	March 17	PI(A)-1	2.13	2.95	1.38	5.536	0.806	0.38	2.51	1.18	3.51	C	3.80
		PI(A)-2	2.60	3.60	1.38	6.760	0.729	0.38	2.98	1.15	3.98	C	4.43
R ₇	March 31	PI(A)-1	1.20	2.60	2.17	1.028	1.343	1.17	2.37	1.97	3.37	C	3.59
		PI(A)-2	1.40	2.26	1.61	2.279	1.073	0.61	2.01	1.43	3.01	C	3.19
R ₈	April 14	PI(A)-1	0.26	0.34	1.31	0.837	2.243	0.31	0.57	2.19	1.57	C	0.82
		PI(A)-2	0.32	0.46	1.44	0.731	2.119	0.44	0.76	2.37	1.76	C	1.08

C = Clumped; R = Regular; No. of samples (N) drawn : in PI(A)-1 = 15; in PI(A)-2 = 10

Table 19. Parameters of spatial distribution of *A. gossypii* alate adults on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping (I_{clump})	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (\bar{C})	Pattern of distribution	Mean clump size ($\bar{\lambda}$)
S ₃	November 11	PI(A)-1	0.60	0.52	0.86	-4.500	1.202	-0.14	0.46	0.77	1.46	R	-
		PI(A)-2	0.68	0.61	0.90	-6.600	1.148	-0.10	0.58	0.85	1.58	R	-
V ₁	November 25	PI(A)-1	1.13	2.05	1.81	1.390	1.267	0.81	1.94	1.72	2.94	C	3.04
		PI(A)-2	1.09	1.90	1.74	1.470	1.264	0.74	1.83	1.68	2.83	C	2.83
V ₁	December 9	PI(A)-1	0.86	1.12	1.30	2.840	1.230	0.30	1.16	1.35	2.16	C	1.86
		PI(A)-2	0.92	1.46	1.59	1.570	1.313	0.59	1.51	1.64	2.51	C	2.34
V ₂	December 23	PI(A)-1	0.20	0.26	1.30	0.667	2.549	0.30	0.50	2.50	1.50	C	0.67
		PI(A)-2	0.31	0.34	1.09	3.203	1.881	0.09	0.39	1.26	1.39	C	0.64
V ₃	January 6	PI(A)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(A)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	January 20	PI(A)-1	0.46	0.51	1.11	4.232	1.552	0.11	0.57	1.24	1.57	C	0.87
		PI(A)-2	0.53	0.64	1.21	2.554	1.509	0.21	0.74	1.39	1.74	C	1.16
R ₂	February 3	PI(A)-1	0.60	0.69	1.15	4.000	1.384	0.15	0.75	1.25	1.75	C	1.16
		PI(A)-2	0.86	0.97	1.13	6.723	1.145	0.13	0.99	1.15	1.99	C	1.46
R ₃	February 18	PI(A)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(A)-2	-	-	-	-	-	-	-	-	-	-	-
R ₄	March 2	PI(A)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(A)-2	-	-	-	-	-	-	-	-	-	-	-
R ₅	March 17	PI(A)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(A)-2	-	-	-	-	-	-	-	-	-	-	-
R ₅	March 31	PI(A)-1	0.93	1.29	1.39	2.402	1.221	0.39	1.32	1.42	2.32	C	2.08
		PI(A)-2	0.99	1.47	1.48	2.042	1.225	0.48	1.47	1.48	2.47	C	2.30
R ₆	April 14	PI(A)-1	1.46	2.28	1.56	2.599	1.034	0.56	2.02	1.38	3.02	C	3.19
		PI(A)-2	1.65	3.15	1.91	1.815	1.076	0.91	2.56	1.53	3.56	C	4.00

C = Clumped; R = Regular; No. of samples (N) drawn : in PI(A)-1 = 15; in PI(A)-2 = 10; - indicates no alate adult available

Iwao's patchiness regressions for *A. gossypii* adults were found as $X^* = 0.356 + 1.320 \bar{X}$ in PI (A) - 1 and $X^* = -1.366 + 2.390 \bar{X}$ in PI (A) - 2 for apterous adults and $X^* = -0.025 + 1.433 \bar{X}$ in PI(A) - 1 and $X^* = -0.062 + 1.539 \bar{X}$ in PI (A) - 2 for alate adults, which are shown in Figure 13A and 13B and Figure 13C and 13D, respectively.

The indices of basic contagion (0.356, -1.366, -0.025 and -0.062) indicated that the adults had a tendency of colony formation in one case when sampled by PI (A) - 1 but tends to be distributed singly in a regular manner in other three cases. However, the density contagiousness coefficients [1.320 and 2.390 (apterae) and 1.433 and 1.539 (alatae)] clearly confirmed that the adults would tend to over disperse at higher densities. F-test found to be significant at $P = 0.05$ level, signified good fit of the models with different methods of sampling.

Regression for Taylor's power law were worked out as $\log S^2 = 0.131 + 1.329 \log \bar{X}$ in PI (A) - 1 and $\log S^2 = 0.153 + 1.508 \log \bar{X}$ in PI (A) - 2 (apterae) and $\log S^2 = 0.079 + 1.075 \log \bar{X}$ in PI (A) - 1 and $\log S^2 = 0.102 + 1.269 \log \bar{X}$ in PI (A) - 2 (alatae), represented graphically in Figure 14A and 14B, and Figure 14C and 14D, respectively.

The values of index of aggregation were found to be invariably higher than unity in all the cases. This indicated that the aggregations were distributed in a clumped manner in the brinjal crop. The R^2 values (Table 14) indicated that 59.10 - 71.40 per cent and 86.50 - 89.10 per cent variation in dispersion of both apterous and alate adults in PI (A) - 1 and PI (A) - 2, respectively could be explained by the Taylor's power law models. The models gave good fit in all the sampling methods as confirmed by F-test, which was significant at $P = 0.01$ level of probability.

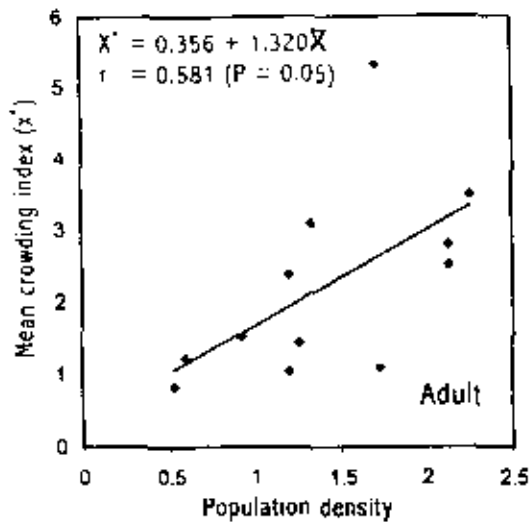


Fig. 13A

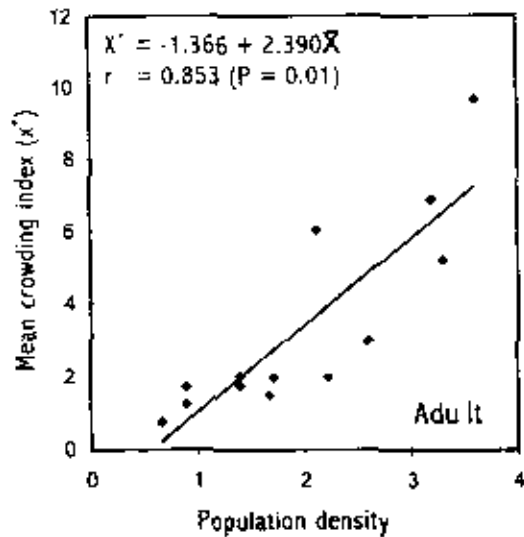


Fig. 13B

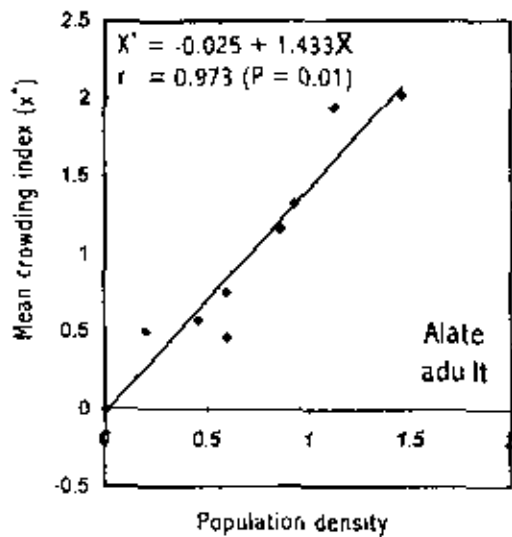


Fig. 13C

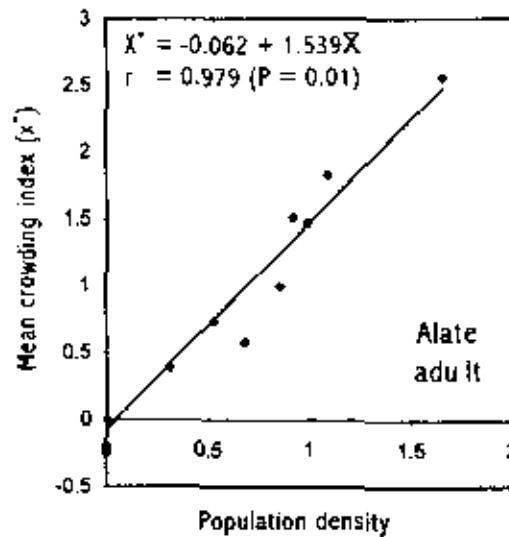


Fig. 13D

Fig. 13. Iwao's patchiness regressions of *A. gossypii* apterous adults (A, B) and alate adults (C, D) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1999-2000

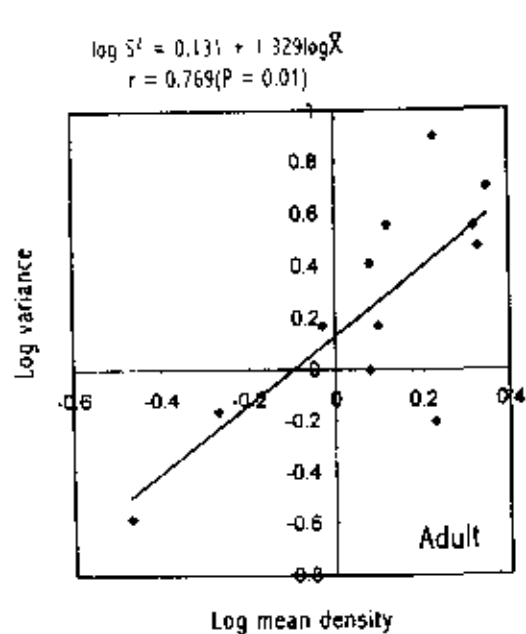


Fig. 14A

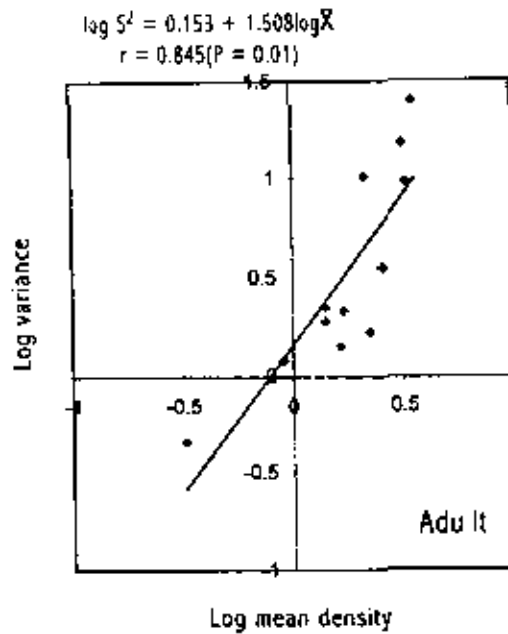


Fig. 14B

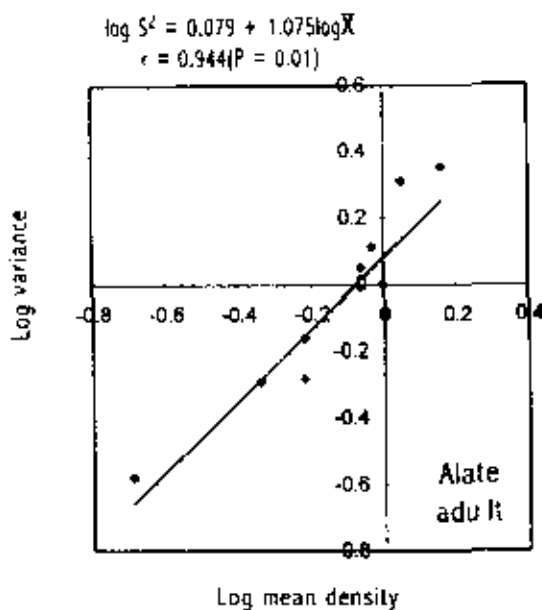


Fig. 14C

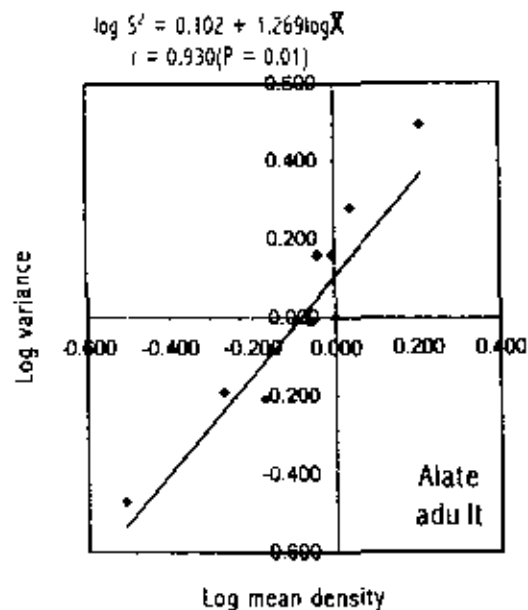


Fig. 14D

Fig. 14. Taylor's power law regressions of *A. gossypii* apterous adults (A, B) and alate adults (C, D) on brinjal, under sampling methods PI(A)-1 and PI(A)-2, respectively, during 1999-2000

4.8.5 Spatial distribution pattern of immature stages of *H. vigintioctopunctata* on brinjal during 1998 – 1999

The parameters concerning the distribution pattern of egg clusters, larvae and pupae of *H. vigintioctopunctata* are presented in Table 20, 21 and 22.

The immature stages of the beetle were first noticed in the field in the form of egg clusters (11 November), larvae (14 October) and pupae (28 October) when the crop attained a stage between S_3 and V_1 . The peak density of egg clusters [0.96/2 branches in PI (L) – 1 and 1.25/3 branches in PI (L) – 2], larvae population [23.20/2 branches in PI (L) – 1 and 37.30/3 branches in PI (L) – 2] and pupal population [8.13/2 branches in PI (L) – 1 and 10.75/3 branches in PI (L) – 2] was found in 18 February, 4 March and 18 March, respectively. After attaining the peak, the population followed a declining trend.

The variance to mean ratio of egg cluster population was found to be less than unity in eight different cases for all the sampling methods. This was indicative of random deposition pattern of eggs by the adult. With the increase in number of egg clusters, there appeared to be some degree of aggregation of egg clusters as seen from the remaining values of the ratios. All the larval and pupal stages of the coccinellid beetle showed aggregative nature of dispersion except on one or two sampling dates.

The value of the dispersion parameters 'k' for egg clusters was low (< 8), which indicated a fairly high degree of clumping from November till first week of March, and the remaining part of the season, they exhibited random distribution. For all the larval and pupal stages of the plant, the 'k' values stood below eight in almost all the sampling occasions except one or two, when the population was at its higher mean densities. It

Table 20. Parameters of spatial distribution of *H. vigintioctopunctata* egg clusters on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping (I_{low})	Mean crowding index (\bar{X})	Mean patchiness index (\bar{X}/\bar{X})	Mean colony size (C')	Pattern of distribution	Mean clump size (λ)
S ₁	October 14	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₁	October 28	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
	November 11	PI(L)-1	0.16	0.14	0.87	-1.250	2.338	-0.13	0.03	0.19	1.03	R	-
		PI(L)-2	0.28	0.40	1.43	0.653	2.258	0.43	0.71	2.53	1.71	C	0.96
November 25	PI(L)-1	0.23	0.31	1.35	0.661	2.420	0.35	0.58	2.52	1.58	C	0.78	
	PI(L)-2	0.38	0.58	1.53	0.722	2.000	0.53	0.91	2.39	1.91	C	1.24	
V ₂	December 9	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₃	December 23	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	January 7	PI(L)-1	0.16	0.16	1.23	0.563	3.076	0.23	0.36	2.77	1.36	C	0.47
		PI(L)-2	0.20	0.20	1.25	0.640	2.795	0.25	0.41	2.56	1.41	C	0.56
R ₂	January 21	PI(L)-1	0.46	0.46	3.06	6.133	1.577	0.06	0.49	1.14	1.49	C	0.75
		PI(L)-2	0.65	0.91	1.40	1.615	1.604	0.40	1.05	1.61	2.05	C	1.65
R ₃	February 4	PI(L)-1	1.73	4.27	2.47	1.177	1.194	1.47	3.20	1.85	4.20	C	4.92
		PI(L)-2	1.65	3.81	2.31	1.259	1.183	1.31	2.96	1.79	3.96	C	4.56
R ₄	February 18	PI(L)-1	0.96	1.72	1.79	1.210	1.366	0.79	1.75	1.82	2.75	C	2.69
		PI(L)-2	1.25	3.61	2.89	0.533	1.520	1.89	3.14	2.51	4.14	C	4.61
R ₅	March 4	PI(L)-1	0.56	0.66	1.18	3.100	1.450	0.18	0.74	1.32	1.74	C	1.16
		PI(L)-2	1.20	0.90	0.75	-4.000	0.790	-0.25	0.95	0.79	1.95	R	-
R ₆	March 18	PI(L)-1	0.36	0.27	0.75	-1.444	1.443	-0.25	0.11	0.30	1.11	R	-
		PI(L)-2	0.65	0.53	0.81	-3.500	1.120	-0.19	0.46	0.71	1.46	R	-
R ₇	April 1	PI(L)-1	0.36	0.25	0.68	-1.181	1.389	-0.32	0.04	0.11	1.04	R	-
		PI(L)-2	0.45	0.26	0.58	-1.052	1.133	-0.42	0.03	0.07	1.03	R	-
April 16	April 16	PI(L)-1	0.10	0.09	0.90	-1.000	3.000	-1.10	0.00	-	1.00	R	-
		PI(L)-2	0.15	0.10	0.67	-0.4000	2.108	-0.33	-0.18	-1.20	0.82	R	-

C = Clumped, R = Regular, - indicates no egg available
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

Table 21. Parameters of spatial distribution of *H. vigintioctopunctata* larvae on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping ($I_{(Dw)}$)	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{R})	Mean colony size (C')	Pattern of distribution	Mean clump size (A)
S ₃	October 14	PI(L)-1	0.40	0.38	0.95	-8.000	1.541	-0.05	0.35	0.87	1.35	R	-
		PI(L)-2	0.62	0.39	0.63	-1.652	1.007	-0.37	0.29	0.47	1.29	R	-
V ₁	October 28	PI(L)-1	1.56	2.63	1.68	2.271	1.039	0.68	2.24	1.43	3.24	C	3.56
		PI(L)-2	1.82	2.74	1.50	3.597	0.909	0.50	2.32	1.37	3.32	C	3.64
V ₁	November 11	PI(L)-1	0.90	1.38	1.53	1.687	1.305	0.53	1.43	1.59	2.43	C	2.27
		PI(L)-2	1.12	2.31	2.06	1.050	1.357	1.06	2.18	1.95	3.18	C	3.29
V ₂	November 25	PI(L)-1	1.40	3.60	2.57	0.890	1.355	1.57	2.97	2.12	3.97	C	4.37
		PI(L)-2	1.77	2.72	1.54	3.297	0.932	0.54	2.31	1.30	3.31	C	3.62
V ₂	December 9	PI(L)-1	0.43	0.48	1.12	3.698	1.611	0.12	0.55	1.28	1.55	C	0.85
		PI(L)-2	0.72	0.98	1.36	1.994	1.375	0.36	1.08	1.50	2.08	C	1.71
V ₁	December 23	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	January 7	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	January 21	PI(L)-1	0.56	0.87	1.55	1.011	1.665	0.55	1.11	1.98	2.11	C	1.66
		PI(L)-2	1.05	1.20	1.14	7.333	1.043	0.14	1.19	1.13	2.19	C	1.75
R ₁	February 4	PI(L)-1	3.03	4.79	1.58	5.215	0.722	0.58	3.61	1.19	4.61	C	5.49
		PI(L)-2	5.60	9.41	1.68	8.230	0.547	0.68	6.28	1.12	7.28	C	9.14
R ₄	February 18	PI(L)-1	10.33	20.34	1.97	10.659	0.436	0.97	11.30	1.09	12.30	C	16.03
		PI(L)-2	20.80	89.32	4.29	6.314	0.454	3.29	24.09	1.16	25.09	C	36.58
R ₄	March 4	PI(L)-1	23.26	96.60	4.16	7.332	0.423	3.16	26.36	1.14	27.36	C	38.83
		PI(L)-2	37.30	263.06	7.05	6.162	0.434	6.05	43.35	1.16	44.35	C	64.95
R ₅	March 18	PI(L)-1	1.80	5.43	3.02	0.892	1.294	2.02	3.82	2.12	4.82	C	5.62
		PI(L)-2	3.60	25.30	7.03	0.597	1.397	6.03	9.63	2.18	10.63	C	12.81
R ₆	April 1	PI(L)-1	0.90	1.89	2.10	0.818	1.527	1.10	2.00	2.22	3.00	C	2.89
		PI(L)-2	1.00	1.31	1.31	3.225	1.144	0.31	1.31	1.31	2.31	C	2.06
R ₆	April 16	PI(L)-1	0.16	0.19	1.19	0.833	2.724	0.19	0.35	2.18	1.35	C	0.50
		PI(L)-2	0.35	0.40	1.14	2.400	1.807	0.14	0.49	1.40	1.49	C	0.78

C = Clumped, R = Regular; - indicates no larva available
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

Table 22. Parameters of spatial distribution of *H. vigintioctopunctata* pupae on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping (low)	Mean crowding index (\bar{X})	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C)	Pattern of distribution	Mean clump size (A)
S ₃	October 14	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₁	October 28	PI(L)-1	0.20	0.16	0.80	-1.000	2.000	-0.20	0.00	-	1.00	R	-
		PI(L)-2	0.37	0.26	0.70	-1.273	1.378	-0.30	0.07	0.18	1.07	R	-
	November 11	PI(L)-1	0.40	0.29	0.72	-1.454	1.346	-0.28	0.12	0.30	1.12	R	-
		PI(L)-2	0.58	0.49	0.84	-3.777	1.206	-0.16	0.42	0.72	1.42	R	-
November 25	PI(L)-1	0.33	0.48	1.45	0.726	2.099	0.45	0.78	2.36	1.78	C	1.07	
	PI(L)-2	0.54	0.69	1.28	1.944	1.538	0.28	0.82	1.52	1.82	C	1.29	
V ₂	December 9	PI(L)-1	0.83	2.18	2.63	0.510	1.779	1.63	2.46	2.96	3.46	C	3.12
		PI(L)-2	0.95	2.43	2.56	0.609	1.640	1.56	2.51	2.64	3.51	C	3.33
V ₃	December 23	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	January 7	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₂	January 21	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₃	February 4	PI(L)-1	1.63	2.72	1.67	2.431	1.011	0.67	2.30	1.41	3.30	C	3.63
		PI(L)-2	2.70	4.64	1.72	3.757	0.797	0.72	3.42	1.27	4.42	C	5.32
	February 18	PI(L)-1	1.03	1.75	1.70	1.472	1.284	0.70	1.73	1.68	2.73	C	2.72
		PI(L)-2	2.35	2.66	1.13	17.806	0.694	0.13	2.48	1.05	3.48	C	3.33
R ₄	March 4	PI(L)-1	5.80	33.71	5.81	1.205	1.000	4.81	10.61	1.33	11.61	C	16.25
		PI(L)-2	9.20	14.48	1.57	16.030	0.414	0.57	9.77	1.06	10.77	C	13.27
R ₅	March 18	PI(L)-1	8.13	74.18	9.12	1.001	1.059	8.12	16.25	1.99	17.25	C	24.35
		PI(L)-2	10.75	69.80	6.49	1.956	0.777	5.49	16.24	1.51	17.24	C	25.68
R ₄	April 1	PI(L)-1	0.23	0.32	1.39	0.535	2.459	0.39	0.62	2.69	1.62	C	0.85
		PI(L)-2	0.56	0.81	1.45	1.240	1.607	0.45	1.01	1.80	2.01	C	1.54
April 16	April 16	PI(L)-1	0.10	0.09	0.90	-1.000	3.000	-0.10	0.00	-	1.00	R	-
		PI(L)-2	0.20	0.25	1.25	0.800	2.500	0.25	0.45	2.25	1.45	C	0.64

C = Clumped, k = Regular; - indicates no pupa available
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

proved high amounts of aggregation among the population of larvae and pupae. Confirmation of the results of dispersion was also found from the findings of David and Moore's index of clumping, mean crowding index, Lloyd's patchiness index and mean colony size. Similarly, mean clump size also confirmed this observation. Mean clump sizes greater than two were found in majority of cases for larval and pupal population and majority of the egg cluster counts, where clump sizes were less than two, which indicated that the clumping of egg clusters could be due to the micro-environmental heterogeneity in the brinjal fields and clumping of larvae and pupae could be due to the behaviour of larvae and pupae and environmental variation in the crop field.

Iwao's patchiness regressions computed under PI (L) - 1 and PI (L) - 2 methods for *H. vigintioctopunctata* egg clusters ($X^* = -0.136 + 1.835\bar{X}$ and $X^* = -0.056 + 1.698\bar{X}$), larvae ($X^* = 0.465 + 1.110\bar{X}$ and $X^* = 0.524 + 1.151\bar{X}$) and pupae ($X^* = -0.110 + 1.949\bar{X}$ and $X^* = 0.004 + 1.317\bar{X}$) are shown in Figure 15A and 15B, 15C and 15D, and 15E and 15F, respectively.

In the case of egg clusters in both sampling methods and pupae in PI (L) - 1 method, the indices of basic contagion were less than zero, which clearly indicated that a single egg cluster or pupae form the basic contagion of the colony or regularly distributed. However, the indices in case of larvae in both the sampling methods and pupae in PI (L) - 2 method were less than unity, which signified that the larvae and pupae were not dispersed in an aggregated manner. The R^2 values (Table 23) indicated that 76.50 - 99.30 per cent variation in dispersion of immature insects in all the sampling methods could be explained by the Iwao's patchiness regression model. The values of F

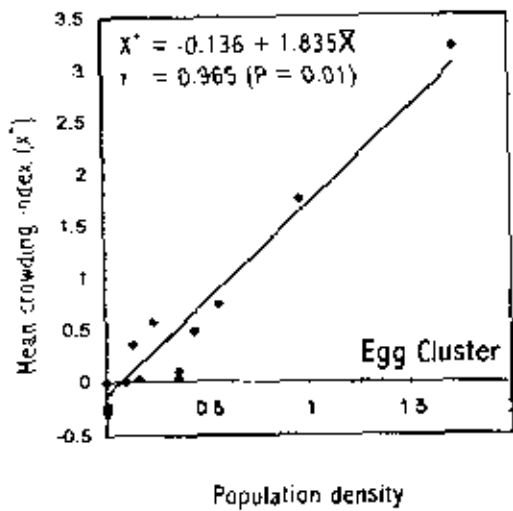


Fig. 15A

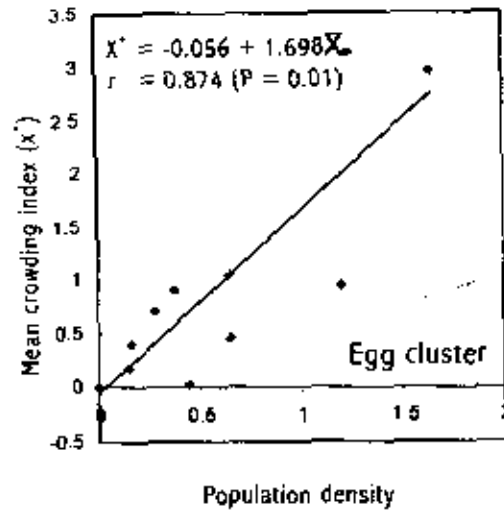


Fig. 15B

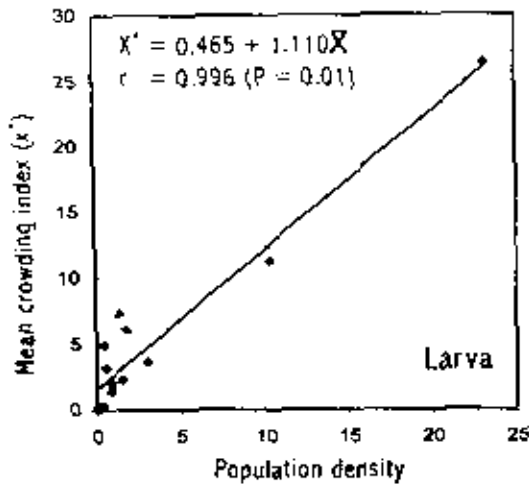


Fig. 15C

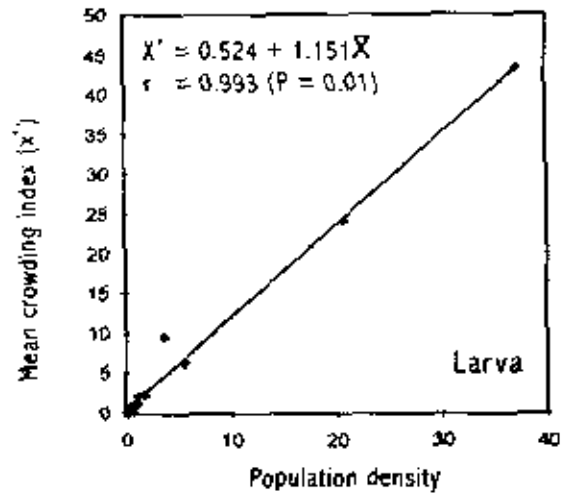


Fig. 15D

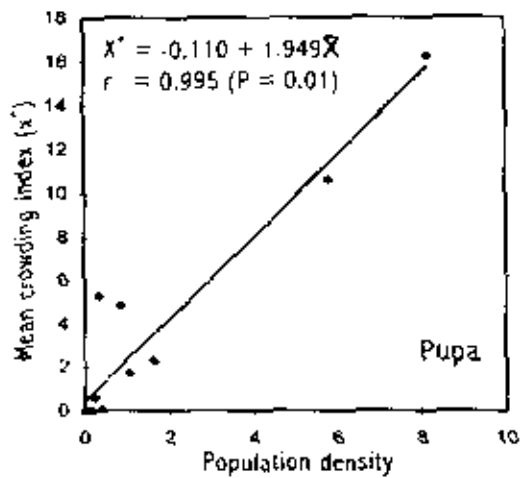


Fig. 15E

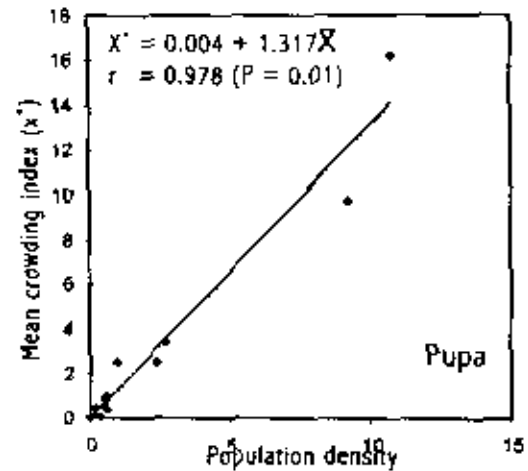


Fig. 15F

Fig. 15. Iwao's patchiness regressions of *H. vigintioctopunctata* egg clusters (A, B), larvae (C, D) and pupae (E, F) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1998-99

(Table 23) which were significant at 1% level of significance, confirmed the goodness of fit of the models.

The regression equation based on Taylor's power law were $\log S^2 = 0.091 + 1.154 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.093 + 1.178 \log \bar{X}$ in PI (L) - 2 for egg clusters, $\log S^2 = 0.189 + 1.247 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.114 + 1.451 \log \bar{X}$ in PI (L) - 2 for larvae and $\log S^2 = 0.237 + 1.479 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.111 + 1.312 \log \bar{X}$ in PI (L) - 2 for pupae are shown in Figure 16A and 16B, 16C and 16D, and 16E and 16F, respectively.

The indices of aggregation were found to be invariably higher than one in all the cases, which indicated that the aggregation were distributed in a clumped manner in the brinjal crop. The R^2 values (Table 23) indicated that more than 81.60 per cent variation in dispersion of the immature beetles in all the sampling methods could be explained by the Taylor's power law regression model.

Highly significant F test (Table 23) at $P = 0.01$ confirmed goodness of fit of these models.

4.8.6 Spatial distribution pattern of *H. vigintioctopunctata* adults on brinjal during 1998 - 1999

Table 24 shows that statistical parameters for spatial distribution pattern of *H. vigintioctopunctata* adults on brinjal crop.

The adults was first detected on 14 October, when the crop was at the seedling (S_3) stage. The peak adult population (3.53 adult/2 branches in PI (A) - 1 and 7.10

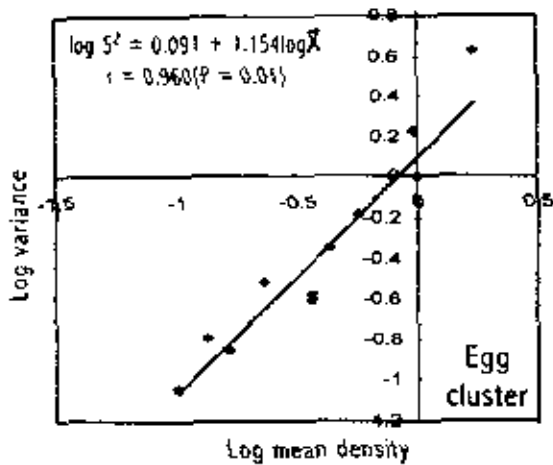


Fig. 16A

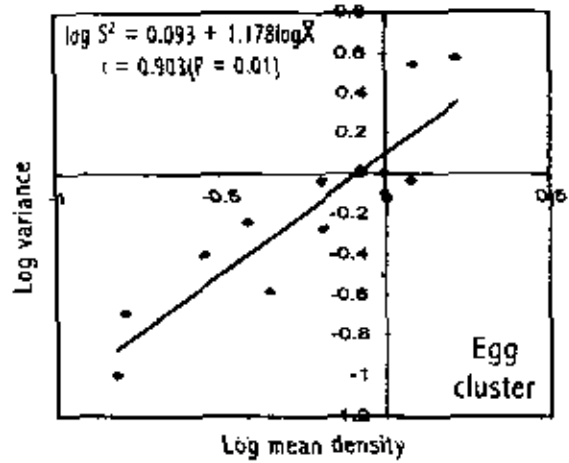


Fig. 16B

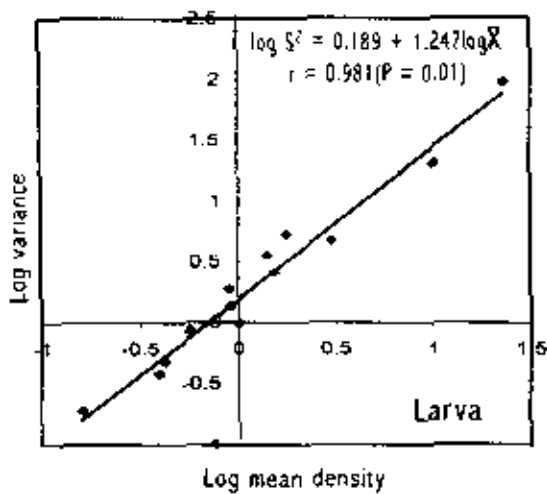


Fig. 16C

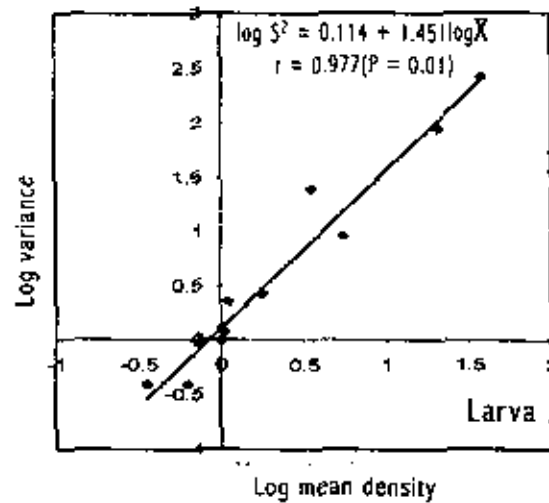


Fig. 16D

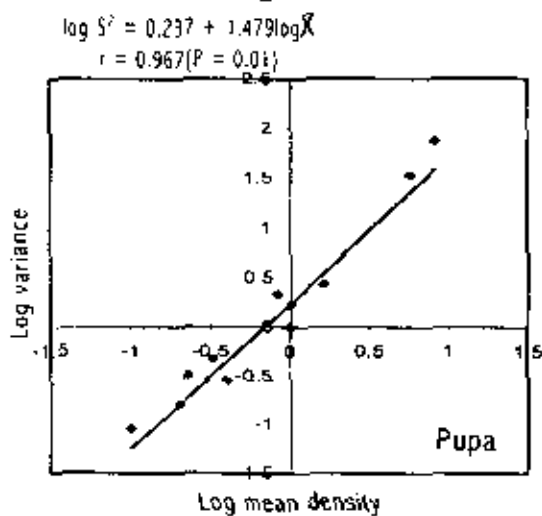


Fig. 16E

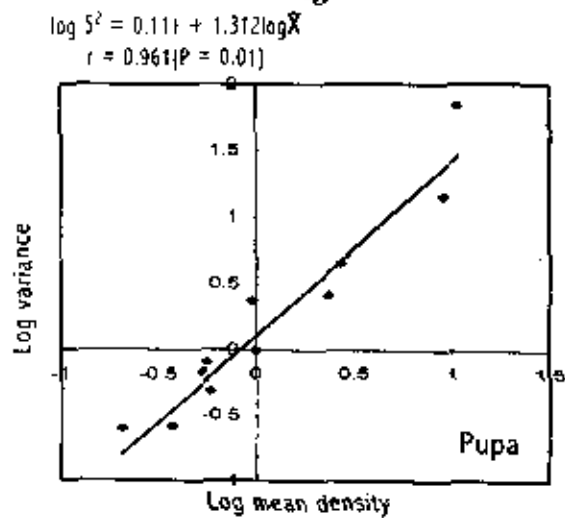


Fig. 16F

Fig. 16. Taylor's power law regressions of *H. vigintioctopunctata* egg clusters (A, B), larvae (C, D) and pupae (E, F) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1998-99

Table 23. Taylor's power law and Iwao's patchiness regression parameters for spatial distribution of *H. vigintioctopunctata* during 1998-99 and 1999-2000

Crop season	Sampling method	Taylor's power law				
		Larva	Pupa	Adult	Egg cluster	
1998-99	PI(L)-1	a	0.189	0.237	0.153	0.091
		b	1.247 ^c	1.479 ^c	1.462 ^c	1.154 ^c
		R ²	0.963	0.935	0.891	0.921
		F	311.89**	173.41**	97.74**	138.99**
	PI(L)-2	a	0.114	0.111	0.089	0.093
		b	1.451 ^c	1.312 ^c	1.162 ^c	1.178 ^c
		R ²	0.955	0.923	0.838	0.816
		F	252.30**	144.75**	61.88**	53.29**
1999-2000	PI(L)-1	a	0.240	0.163	0.285	0.079
		b	1.590 ^c	1.541 ^c	1.244 ^c	1.102 ^c
		R ²	0.917	0.834	0.808	0.847
		F	110.83**	50.39**	41.99**	55.56**
	PI(L)-2	a	0.202	0.144	0.156	0.107
		b	1.662 ^c	1.532 ^c	1.158 ^c	1.250 ^c
		R ²	0.923	0.887	0.768	0.824
		F	119.14**	78.24**	33.109**	46.66**

Iwao's patchiness regression

1998-99	PI(L)-1	α	0.465	-0.110	-0.191	-0.136
		β	1.110 ^c	1.949 ^c	1.592 ^c	1.835 ^c
		R ²	0.993	0.991	0.918	0.931
		F	1718.30**	1341.38**	134.44**	161.84**
	PI(L)-2	α	0.524	0.004	0.252	-0.056
		β	1.151 ^c	1.317 ^c	1.069 ^c	1.698 ^c
		R ²	0.986	0.957	0.930	0.765
		F	843.65**	269.10**	159.72**	38.97**
1999-2000	PI(L)-1	α	0.250	0.130	0.274	-0.128
		β	1.881 ^c	1.559 ^c	1.273 ^c	2.512 ^c
		R ²	0.965	0.846	0.669	0.943
		F	272.545**	54.96**	18.21**	148.67**
	PI(L)-2	α	0.485	0.101	0.347	-0.145
		β	1.632 ^c	1.815 ^c	1.100 ^c	2.486 ^c
		R ²	0.975	0.990	0.803	0.940
		F	394.87**	962.14**	36.71**	142.11**

** Significant at $P = 0.01$

^c Clumped

adults/3 branches in PI (A) - 2] was recorded on 18 March when the crop attained fruiting stage.

The variance to mean ratios were greater than unity for 19 cases out of 28 cases, indicating contagiousness of distribution of adults. The exponent 'k' values were low (<8) in almost all the sampling dates, indicating a fairly high degree of clumping, except a few sampling dates where values of 'k' was found negative, which signified regularity of distribution of adults. David and Moore's index of clumping were also positive in those cases, where, the distribution was found aggregated by the other statistical methods. Similarly, Lloyd's indices of mean crowding and patchiness index were indicative of the previous results. Mean clump size less than two were found during early, mid and later part of the crop season, which suggested that the clumpings were due to environmental heterogeneity in the crop field. Higher clump size (>2) in remaining part of the crop season justified that clumping was due to environmental heterogeneity as well as active behaviour of the adults.

Iwao's patchiness regressions for *H. vigintioctopunctata* adults under PI (L) - 1 and PI (L) - 2 sampling methods were $X^* = -0.191 + 1.592\bar{X}$ (Figure 17A) and $X^* = 0.252 + 1.069\bar{X}$ (Figure 17B), respectively.

The indices of basic contagion (-0.191 and 0.252) being less than one suggested that the adults had a tendency of colony formation. But negative index in PI (L) - 1 method suggested that a single adult formed the basic contagion of the colony. As the density contagiousness coefficient (1.592 and 1.069) were greater than unity, the adults were found to be over-dispersed. The R^2 values as shown in Table 23 signified that 91.80

Table 24. Parameters of spatial distribution of *H. vigintioctopunctata* adults on brinjal during 1998-99

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Co-efficient of variation (CV)	Index of clumping ($\ln W$)	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C')	Pattern of distribution	Mean clump size (A)
S ₁	October 14	PI(L)-1	0.43	0.25	0.58	-1.000	1.162	-0.42	0.01	0.02	1.01	R	-
		PI(L)-2	0.58	0.44	0.76	-2.428	1.143	-0.24	0.34	0.58	-	1.34	R
V ₁	October 28	PI(L)-1	0.50	0.25	0.50	-1.000	1.000	-0.50	0.00	-	1.00	R	-
		PI(L)-2	0.86	0.63	0.73	-3.217	0.923	-0.27	0.59	0.69	1.59	R	-
V ₂	November 11	PI(L)-1	0.50	0.36	0.72	-1.785	1.200	-0.28	0.22	0.44	1.22	R	1.72
		PI(L)-2	0.69	0.96	1.39	1.777	1.419	0.39	1.08	1.56	2.08	C	2.69
V ₃	November 25	PI(L)-1	0.80	1.76	2.20	0.667	1.658	1.20	2.00	2.50	3.00	C	3.18
		PI(L)-2	1.16	2.23	1.92	1.260	1.287	0.92	2.08	1.79	3.08	C	1.76
V ₄	December 9	PI(L)-1	0.63	0.97	1.53	1.167	1.563	0.53	1.16	1.84	2.16	C	4.13
		PI(L)-2	0.89	2.15	2.41	0.624	1.647	1.41	2.30	2.58	3.30	C	1.08
R ₁	December 23	PI(L)-1	0.30	0.46	1.53	0.562	2.260	0.53	0.83	2.77	1.83	C	1.67
		PI(L)-2	0.46	0.82	1.78	0.587	1.968	0.78	1.24	2.69	2.24	C	0.95
R ₂	January 7	PI(L)-1	0.40	0.48	1.20	2.000	1.732	0.20	0.60	1.50	1.50	C	-
		PI(L)-2	1.00	0.84	0.84	-6.250	0.916	-0.16	0.84	0.84	1.84	R	-
R ₃	January 21	PI(L)-1	0.33	0.28	0.84	-2.200	1.603	-0.16	0.17	0.50	1.17	R	-
		PI(L)-2	0.75	0.61	0.81	-4.000	1.041	-0.19	0.58	0.77	1.58	R	-
R ₄	February 4	PI(L)-1	1.46	1.77	1.21	6.870	0.911	0.21	1.67	1.14	2.67	C	2.48
		PI(L)-2	2.25	3.82	1.70	3.223	0.868	0.70	2.95	1.31	3.95	C	4.63
R ₅	February 18	PI(L)-1	1.76	3.56	2.09	1.716	1.072	1.09	2.85	1.62	3.85	C	4.39
		PI(L)-2	2.85	4.34	1.52	5.449	0.731	0.52	3.37	1.18	4.37	C	5.10
R ₆	March 4	PI(L)-1	0.63	0.79	1.20	3.076	1.383	0.20	0.83	1.32	1.83	C	1.31
		PI(L)-2	1.65	1.39	0.84	-10.461	0.714	-0.16	1.49	0.09	2.49	R	-
R ₇	March 18	PI(L)-1	3.53	10.11	2.86	1.893	0.900	1.86	5.39	1.53	6.39	C	8.57
		PI(L)-2	7.1	11.59	1.63	11.227	0.479	0.63	7.73	1.09	8.73	C	10.90
R ₈	April 1	PI(L)-1	1.66	2.98	1.79	2.083	1.039	0.79	2.45	1.47	3.45	C	3.90
		PI(L)-2	2.70	4.53	1.68	3.983	0.788	0.68	3.38	1.25	4.38	C	5.25
R ₉	April 16	PI(L)-1	0.46	0.46	1.00	0.000	1.474	0.00	0.46	1.00	1.46	C	-
		PI(L)-2	1.05	1.20	1.14	7.333	1.043	0.14	1.19	1.13	2.19	C	1.76

C = Clumped, R = Regular
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

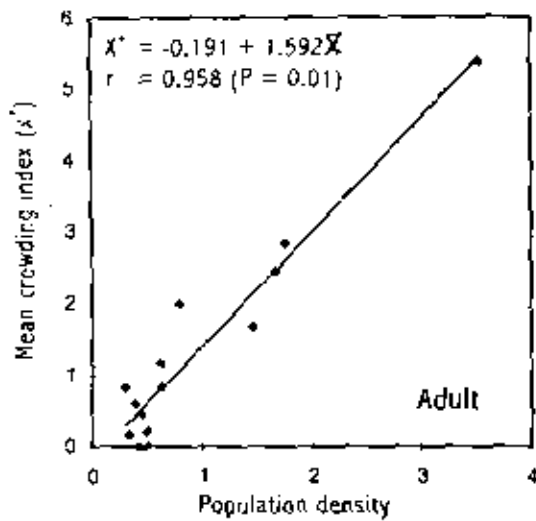


Fig. 17A

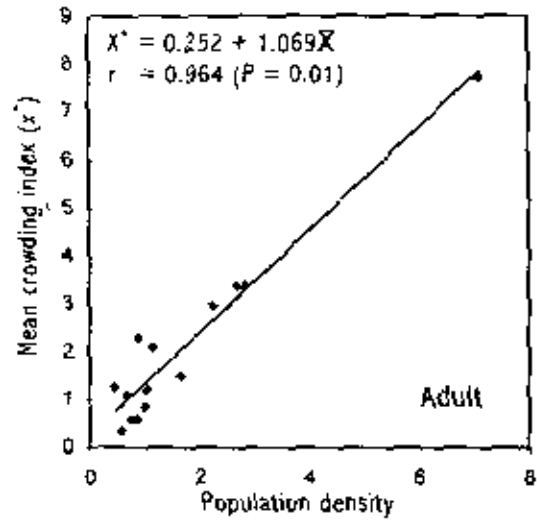


Fig. 17B

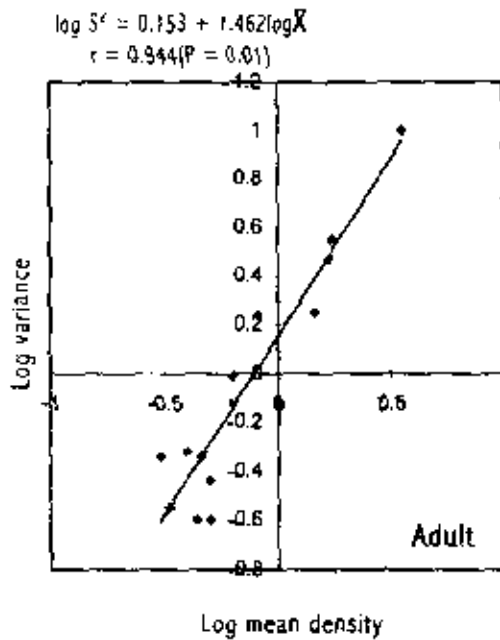


Fig. 18A

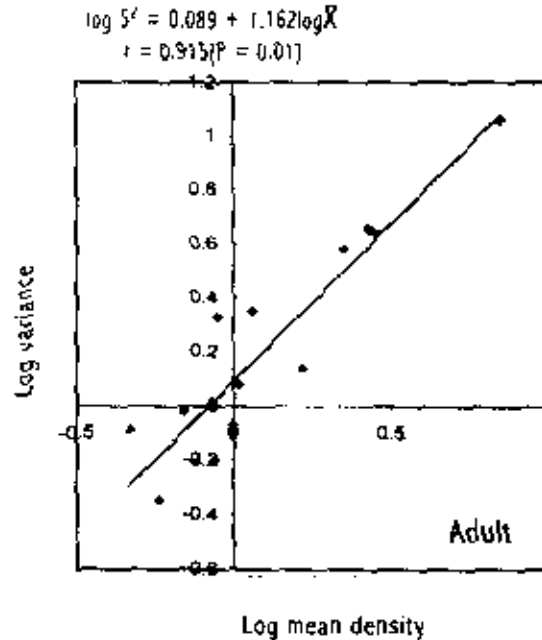


Fig. 18B

Fig. 17. Iwao's patchiness regressions of *H. vigintioctopunctata* adults (A, B) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1998-99

Fig. 18. Taylor's power law regressions of *H. vigintioctopunctata* adults (A, B) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1998-99

and 93.00 per cent variation in adult counts for PI (L) – 1 and PI (L) – 2, respectively, could be explained by the Iwao's patchiness regression model. The fitness of this model was tested by computing F values (Table 23), which were found to be significant ($P = 0.01$) and hence, confirmed goodness of fit of the models in all the sampling methods.

The regressions computed for *H. vigintioctopunctata* adults based on Taylor's power law were $\log S^2 = 0.153 + 1.462 \log \bar{X}$ in PI (L) – 1 and $\log S^2 = 0.089 + 1.162 \log \bar{X}$ in PI (L) – 2 are depicted in Figure 18A and 18B, respectively.

For all the sampling methods, the indices of aggregation were higher than unity and this indicated that the aggregations were over-dispersed on the crop. The model was found to be fit because it explained 83.30 to 89.10 per cent variation in adult distribution as evident by higher R^2 values (Table 23). In addition, the significant F values (Table 23) at $P = 0.01$ confirmed goodness of fit of the models in all the sampling methods.

4.8.7 Spatial distribution pattern of the immature stages of *H. vigintioctopunctata* on brinjal during 1999 – 2000

Statistical parameters describing the nature of dispersion of egg clusters, larval population and pupal population of *H. vigintioctopunctata* are presented in table 25, 26 and 27, respectively.

The appearance of egg clusters, larvae and pupae were first noticeable on 25 November (S_3 crop growth stage), 9 December (V_1 crop growth stage) and 23 December (V_1 crop growth stage), respectively. The attainment of peak population density under PI (L) – 1 and PI (L) – 2 sampling methods for egg clusters (1.36 egg clusters/2 branches and 1.55 egg clusters/3 branches), larvae (8.16 larvae/2 branches and 10.20 larvae/3

branches) and pupae (3.96 pupae/2 branches and 4.28 pupae/3 branches) were recorded at R_3 , R_4 and R_5 stages of the crop, respectively, during February - March. The variance to mean ratios calculated were less than unity in egg cluster counts and larval populations for a single occasion, whereas the rest of the data including pupal counts were higher than unity which suggested aggregated dispersion in all the sampling methods. The values of the ratios tended to increase with the increase in population densities of all the immature stages of the beetle. The highest 'k' values for all the immature stages being 6.00 indicated fairly high degree of clumping in all the sampling methods. Similar finding was also obtained from the statistics of David and Moore's index of clumping, mean crowding index, Lloyd's patchiness index and mean colony size. The mean clump sizes ranged from 0.54 to 5.43 in case of egg cluster counts, 0.71 to 29.48 in case of larval population and 0.58 to 11.62 in case of pupae in different observations. It suggested that the environmental heterogeneity in the crop field alone or the active behaviour of the immature insects in addition were the possible causes of aggregation found in different stages of the crop season.

The Iwao's regression model worked out under $PI(L) - 1$ and $PI(L) - 2$ sampling methods were in order as $X^* = -0.128 + 2.512\bar{X}$ and $X^* = -0.145 + 2.486\bar{X}$ (Figure 19A and 19B), $X^* = 0.250 + 1.881\bar{X}$ and $X^* = 0.485 + 1.635\bar{X}$ (Figure 19C and 19D) and $X^* = 0.130 + 1.559\bar{X}$ and $X^* = 0.101 + 1.815\bar{X}$ (Figure 19E and 19F) for egg cluster counts, larval population and pupal population, respectively.

The indices of basic contagion (- 0.128 and - 0.145) for egg cluster counts indicated that the egg clusters were distributed singly in a regular pattern. However, the

Table 25. Parameters of spatial distribution of *H. vigintioctopunctata* egg clusters on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping ($\ln \bar{X}$)	Mean crowding index (\bar{X})	Lloyd's patchiness index (\bar{X}/\bar{X})	Mean colony size (C')	Pattern of distribution	Mean clump size (λ)
S ₁	November 25	PI(L)-1	0.20	1.13	0.65	-0.571	1.803	-0.35	-0.15	-0.75	0.85	R	-
		PI(L)-2	0.19	0.11	0.58	-0.450	1.745	-0.42	-0.23	-1.21	0.77	R	-
V ₁	December 9	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
December 23	-	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₂	January 6	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₃	January 20	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₂	February 3	PI(L)-1	0.43	0.46	1.07	6.000	1.577	0.07	0.50	1.16	1.50	C	0.75
		PI(L)-2	0.55	0.66	1.80	2.750	1.477	0.20	0.75	1.36	1.75	C	1.11
R ₁	February 17	PI(L)-1	0.20	0.23	1.15	1.333	2.397	0.15	0.35	1.75	1.35	C	0.54
		PI(L)-2	0.40	0.66	1.65	0.615	2.031	0.65	1.05	2.62	2.05	C	1.39
March 2	-	PI(L)-1	1.36	4.28	3.15	0.633	1.521	2.15	3.51	2.58	4.51	C	4.80
		PI(L)-2	1.55	5.31	3.42	0.638	1.486	1.42	3.97	2.56	4.97	C	5.43
R ₄	March 17	PI(L)-1	0.31	0.42	1.35	0.872	2.090	0.35	0.66	2.13	1.66	C	0.95
		PI(L)-2	0.40	0.46	1.15	2.666	1.695	0.15	0.55	1.37	1.55	C	0.87
R ₅	March 31	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₄	April 14	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-

C = Clumped, R = Regular; - indicates no egg available
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

Table 26. Parameters of spatial distribution of *H. viginioctopunctata* larvae on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping ($I_{(loc)}$)	Mean crowding index (\bar{X})	Lloyd's parabiosis index (\bar{X}^2/\bar{X})	Mean colony size (C)	Pattern of distribution	Mean clump size (λ)	
S ₁	November 25	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-	
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-	
V ₁	December 9	PI(L)-1	0.53	0.39	0.73	-2.000	1.178	-0.27	0.26	0.49	1.26	R	-	
		PI(L)-2	0.82	0.61	0.74	-3.196	0.952	-0.26	0.56	0.68	1.56	R	-	
V ₂	December 23	PI(L)-1	0.20	0.27	1.35	0.571	2.598	0.35	0.55	2.75	1.55	C	0.71	
		PI(L)-2	0.28	0.43	1.53	0.523	2.342	0.53	0.81	2.89	1.81	C	1.03	
V ₃	January 6	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-	
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-	
R ₃	January 20	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-	
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-	
R ₃	February 3	PI(L)-1	0.20	0.28	1.40	0.500	2.646	0.40	0.60	3.00	1.60	C	0.77	
		PI(L)-2	0.50	0.97	1.94	0.532	1.970	0.94	1.44	2.88	2.44	2.44	C	1.91
R ₃	February 17	PI(L)-1	0.63	1.29	2.05	0.601	1.803	1.05	1.68	2.67	2.68	C	2.24	
		PI(L)-2	1.20	3.82	3.18	0.550	1.629	2.18	3.38	2.82	4.38	4.38	C	4.42
R ₄	March 2	PI(L)-1	1.80	7.20	4.00	0.600	1.491	3.00	4.80	2.67	5.80	C	6.41	
		PI(L)-2	2.60	14.62	5.62	0.562	1.471	4.62	7.22	2.77	8.22	8.22	C	9.38
R ₄	March 17	PI(L)-1	8.16	97.29	11.92	0.747	1.208	10.92	19.08	2.34	20.08	20.08	C	26.74
		PI(L)-2	10.20	102.37	10.04	1.128	0.991	9.04	19.24	1.87	20.24	20.24	C	29.48
R ₄	March 31	PI(L)-1	2.16	6.39	2.96	1.10	1.17	1.96	4.12	1.91	5.12	5.12	C	6.23
		PI(L)-2	3.42	10.35	3.03	1.69	0.94	2.03	5.45	1.59	6.45	6.45	C	8.57
R ₄	April 14	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-	
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-	

C = Clumped, R = Regular; - indicates no larva available
 No. of samples (N) drawn : in PI(L)-1 = 30; in PI(L)-2 = 20

Table 27. Parameters of spatial distribution of *H. vigintioctopunctata* pupae on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping ($I_{(b,w)}$)	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (C)	Pattern of distribution	Mean clump size (A)
S ₁	November 25	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₁	December 9	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
December 23	December 23	PI(L)-1	0.16	0.21	1.31	0.52	2.860	0.31	0.47	2.94	1.47	C	0.58
		PI(L)-2	0.20	0.27	1.35	0.57	2.600	0.35	0.55	2.75	1.55	C	0.69
V ₂	January 6	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
V ₄	January 20	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₁	February 3	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
R ₃	February 17	PI(L)-1	-	-	-	-	-	-	-	-	-	-	-
		PI(L)-2	-	-	-	-	-	-	-	-	-	-	-
March 2	March 2	PI(L)-1	0.66	1.12	1.69	0.947	1.603	0.69	1.35	2.04	2.35	C	2.01
		PI(L)-2	0.80	1.68	2.10	0.727	1.620	1.10	1.90	2.37	2.90	C	2.59
March 17	March 17	PI(L)-1	1.95	9.67	4.96	0.492	1.594	3.96	5.91	3.03	6.91	C	7.49
		PI(L)-2	2.80	11.01	3.93	0.954	1.185	2.93	5.73	2.05	6.73	C	8.58
March 31	March 31	PI(L)-1	3.96	19.32	4.88	1.02	1.110	3.88	7.84	1.98	8.84	C	11.62
		PI(L)-2	4.28	17.75	4.15	1.36	0.980	3.15	7.43	1.73	8.43	C	10.69
April 14	April 14	PI(L)-1	0.36	0.54	1.50	0.72	2.040	0.50	0.86	2.39	1.86	C	1.17
		PI(L)-2	0.38	0.60	1.58	0.65	2.040	0.58	0.96	2.53	1.96	C	1.30

C = Clumped, - indicates no pupa available

No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

indices of basic contagion for both larval and pupal counts were greater than zero, which indicated that more than one individual of larvae or pupae formed the component of basic contagion and the individuals had a positive association among themselves. During the crop season, the density contagiousness coefficient was greater than unity for all the immature stages of the beetle in all sampling methods, which indicated that the aggregations were distributed in a clumped manner. The R^2 values as shown in Table 23 suggested that 84.60 to 99.00 per cent variation in the population counts of the immature stages of the beetle in all sampling methods could be explained by the Iwao's patchiness regression models. The fitness of these models were tested by computing F values (Table 23), which were found to be significant ($P = 0.01$) and hence, goodness of fit of these models were ascertained.

The regressions describing the Taylor's power law were computed for immature stages of *H. vigintioctopunctata*. These equations were $\log S^2 = 0.079 + 1.102 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.107 + 1.250 \log \bar{X}$ in PI (L) - 1 and PI (L) - 2 for egg clusters, $\log S^2 = 0.240 + 1.590 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.202 + 1.662 \log \bar{X}$ in PI (L) - 2 for larval population and $\log S^2 = 0.163 + 1.541 \log \bar{X}$ in PI (L) - 1 and $\log S^2 = 0.144 + 1.532 \log \bar{X}$ in PI (L) - 2 for pupal population. These models were shown graphically in Figure 20A and 20B, Figure 20C and 20D, and Figure 20E and 20F, respectively.

For all the sampling methods, the indices of aggregation were higher than unity, which was a clear indication of overdispersed nature of aggregation of the immature stages on the crop. The models explained 22.40 to 92.30 per cent variations in distribution of the young beetles as evident from the R^2 values (Table 23). F test showed

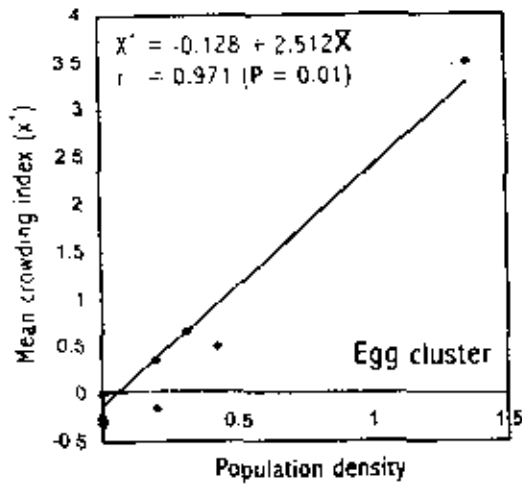


Fig. 19A

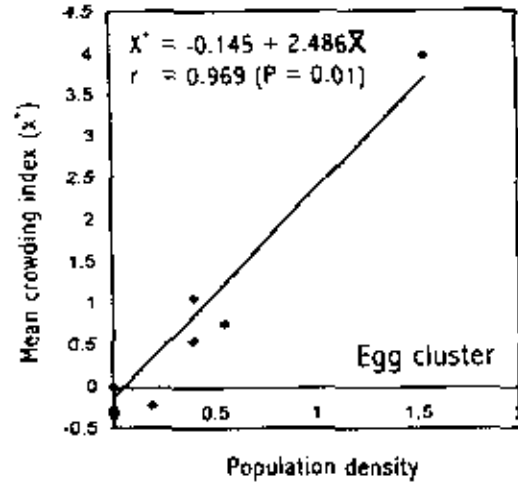


Fig. 19B

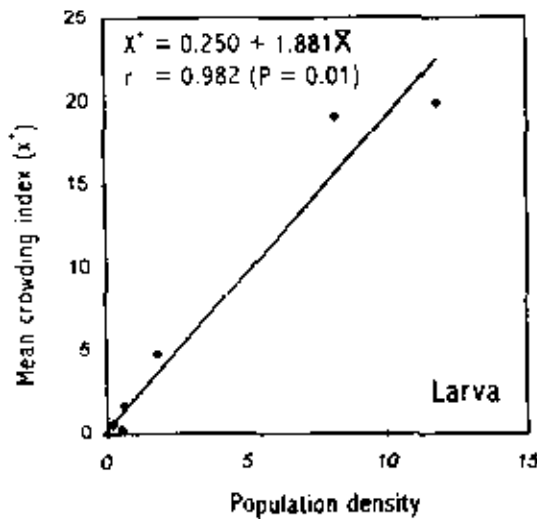


Fig. 19C

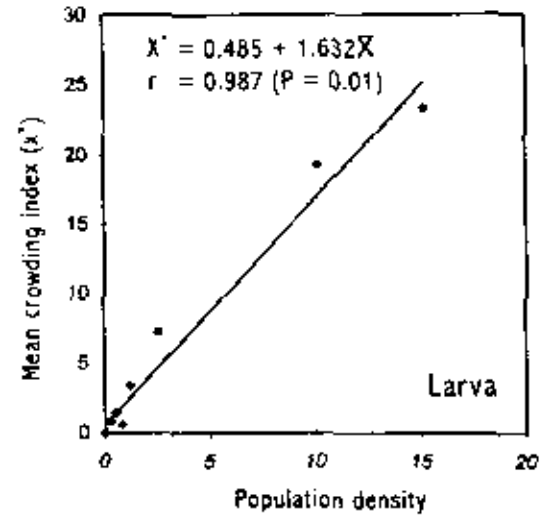


Fig. 19D

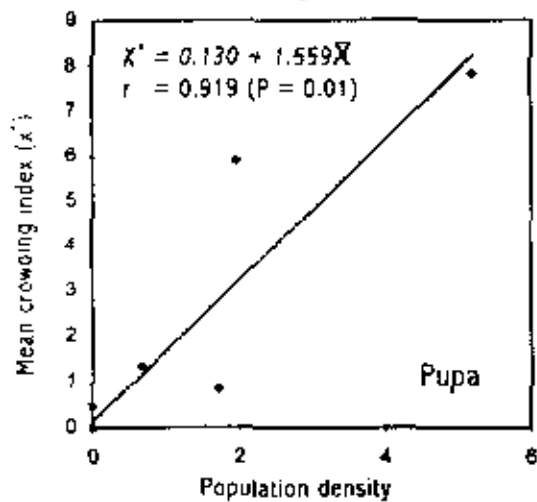


Fig. 19E

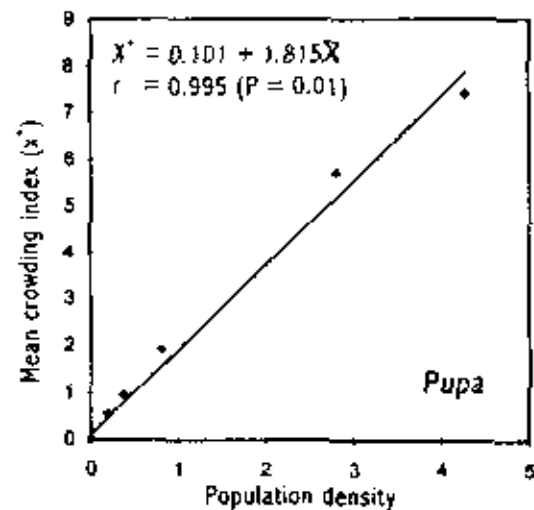
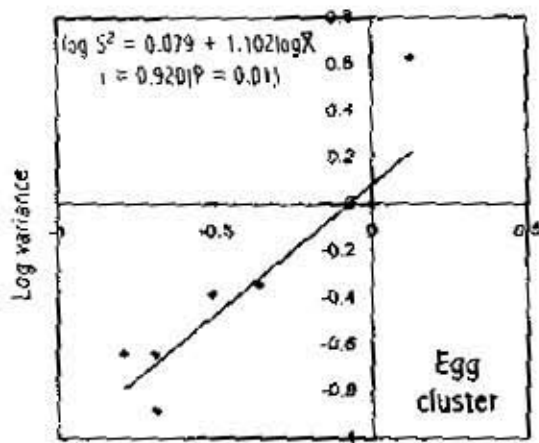


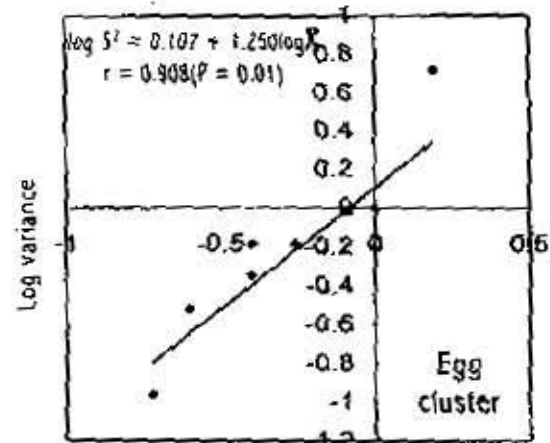
Fig. 19F

Fig. 19. Iwao's patchiness regressions of *H. vigintioctopunctata* egg clusters (A, B), larvae (C, D) and pupae (E, F) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1999-2000



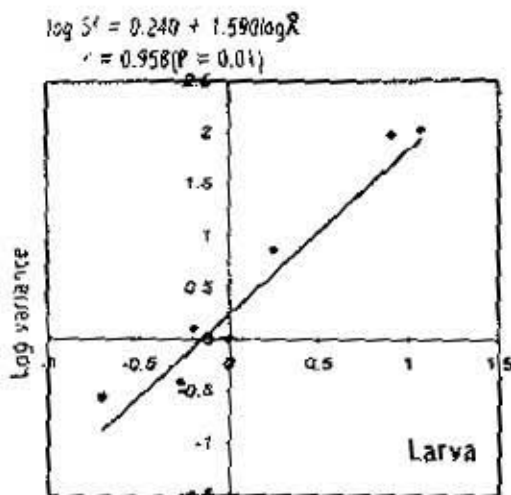
Log mean density

Fig. 20A



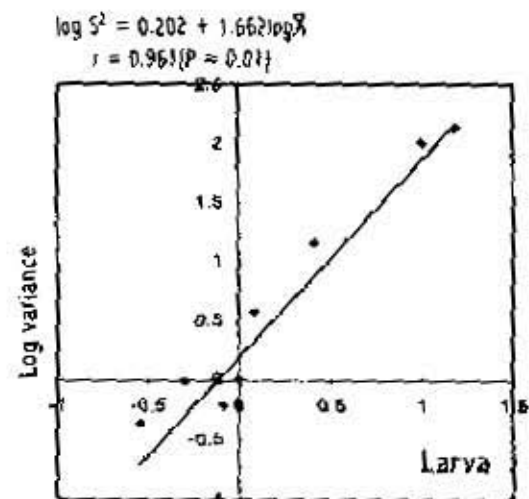
Log mean density

Fig. 20B



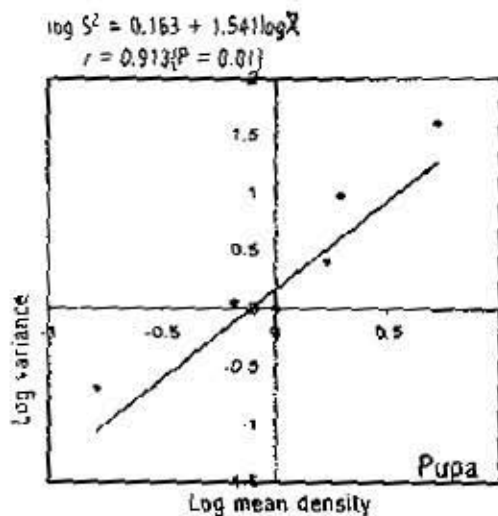
Log mean density

Fig. 20C



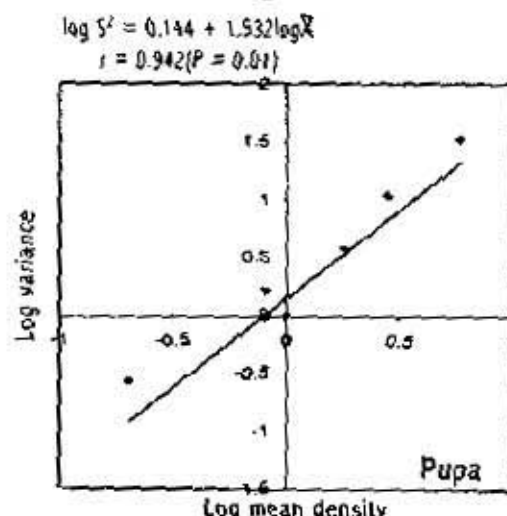
Log mean density

Fig. 20D



Log mean density

Fig. 20E



Log mean density

Fig. 20F

Fig. 20. Taylor's power law regressions of *H. vigintioctopunctata* egg clusters (A, B), larvae (C, D) and pupae (E, F) on brinjaj, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1999-2000

highly significant ($P = 0.01$) results, which confirmed that models had goodness of fit in all the sampling methods.

4.8.8 Spatial distribution pattern of *H. vigintioctopunctata* adults on brinjal during 1999 – 2000

The parameters related to the distribution pattern of *H. vigintioctopunctata* adults on brinjal are shown in Table 28.

The adults made their appearance in the fourth week of November, when the crop was in growth stage S_3 (seedling). Their population rose to peak (2.63 adults/2 branches in PI (L) – 1 and 3.15 adults/3 branches in PI (L) – 2) in the R_5 stage (fruit ripening) during fourth week of March. In all the methods, the variance to mean ratios were greater than unity except in one sampling dates (9 December). This indicated their contagiousness of distribution. The values of exponent 'k' were found to be less than eight in many occasions except in four cases for all the sampling methods, which were indicative of a clumped type of distribution of the adults. The positive values of David and Moore's index of clumping for most of the sampling occasions reflected the contagiousness of dispersion. The indices of mean crowding also were higher than mean population density in similar occasions suggested clumped distribution of adults. Similarity in results were also obtained from the statistics of Lloyd's patchiness index and mean colony size. Mean clump sizes were greater than two for 8 number of cases in all the sampling methods and it may be revealed that clumping of adults could be due to the behaviour of the adults and environmental variation in the crop fields. However,

Table 28. Parameters of spatial distribution of *H. vigintioctopunctata* adults on brinjal during 1999-2000

Crop growth stage	Sampling date	Sampling method	Mean population density (\bar{X})	Variance (S^2)	Variance to mean ratio (S^2/\bar{X})	Dispersion parameter (k)	Coefficient of variation (CV)	Index of clumping (I_{0w})	Mean crowding index (\bar{X}^2)	Lloyd's patchiness index (\bar{X}^2/\bar{X})	Mean colony size (\bar{C})	Pattern of distribution	Mean clump size (\bar{A})
S ₅	November 25	PI(L)-1	0.23	0.32	1.39	0.555	2.459	0.39	0.62	2.69	1.62	C	0.84
		PI(L)-2	0.26	0.38	1.46	0.566	2.370	0.46	0.72	2.77	1.72	C	0.93
V ₁	December 9	PI(L)-1	0.43	0.26	0.60	-1.058	1.185	-0.40	0.03	0.07	1.03	R	-
		PI(L)-2	0.54	0.51	0.94	-9.666	1.322	-0.06	0.48	0.89	1.48	R	-
V ₂	December 23	PI(L)-1	0.10	0.12	1.20	0.500	3.464	0.20	0.30	3.00	1.30	C	0.38
		PI(L)-2	0.17	0.21	1.23	0.700	2.695	0.23	0.40	2.35	1.40	C	0.57
V ₃	January 6	PI(L)-1	0.13	0.14	1.08	1.700	2.878	0.08	0.21	1.61	1.21	C	0.32
		PI(L)-2	0.30	0.33	1.10	4.500	1.914	0.10	0.40	1.33	1.40	C	0.56
R ₁	January 20	PI(L)-1	0.56	0.62	1.11	5.167	1.406	0.11	0.67	1.20	1.67	C	1.02
		PI(L)-2	1.10	1.13	1.12	9.307	0.966	0.12	1.22	1.11	2.22	C	1.75
R ₂	February 3	PI(L)-1	0.53	1.02	1.92	0.571	1.905	0.92	1.45	2.73	2.45	C	1.88
		PI(L)-2	0.75	0.82	1.09	8.000	1.207	0.09	0.84	1.12	1.81	C	1.23
R ₃	February 17	PI(L)-1	0.66	0.74	1.12	5.375	1.303	0.12	0.78	1.18	1.78	C	1.19
		PI(L)-2	1.35	2.99	2.21	1.110	1.281	1.21	2.56	1.90	3.56	C	3.90
R ₄	March 2	PI(L)-1	0.92	1.47	1.60	1.545	1.317	0.60	1.52	1.65	2.52	C	2.37
		PI(L)-2	1.15	1.39	1.20	5.500	1.025	0.20	1.35	1.17	2.35	C	2.06
R ₅	March 17	PI(L)-1	1.32	4.23	3.20	0.600	1.558	2.20	3.52	2.67	4.52	C	4.70
		PI(L)-2	1.45	3.09	2.13	1.280	1.212	1.13	2.58	1.78	3.58	C	4.02
R ₆	March 31	PI(L)-1	2.63	3.45	1.31	8.430	0.710	0.31	2.94	1.12	3.94	C	4.19
		PI(L)-2	3.15	4.19	1.33	9.540	0.650	0.33	3.48	1.10	4.48	C	4.82
R ₆	April 14	PI(L)-1	0.62	1.06	1.71	0.860	1.660	0.71	1.33	2.14	2.33	C	1.92
		PI(L)-2	0.58	1.21	2.09	0.540	1.900	1.09	1.67	2.88	2.67	C	2.03

C = Clumped, R = Regular
 No. of samples (N) drawn : in PI(L) - 1 = 30; in PI(L) - 2 = 20

clump sizes on 12 other cases were less than two, which indicated that clumping was primarily due to environmental variation of the crop fields.

Iwao's patchiness regressions for *H. vigintioctopunctata* adults were $X^* = 0.274 + 1.273\bar{X}$ in PI (L) - 1 and $X^* = 0.347 + 1.100\bar{X}$ in PI (L) - 2 and these are graphically shown in Figure 21A and 21B, respectively.

In all the cases, the indices of basic contagion were higher than zero, thus revealing that there was a positive association among the adults and a group of these adults formed the component of basic contagion. The values of the density contagiousness coefficients exceeded one, indicating clumped distribution of adults on the crop. Coefficient of determination (R^2) values were found to be 0.669X in PI (L) - 1 and 0.803X in PI (L) - 2 (Table 23) signifying that 66.90 per cent and 80.30 per cent variation in adult distribution, respectively, could be explained by the Iwao's patchiness regression model. The values of F (Table 23), which was significant at 1 percent level of significance, confirmed the goodness of fit of the model.

The regression equations based on Taylor's power law were $\log S^2 = 0.285 + 1.244 \log \bar{X}$ in PI (L) - 1 (Figure 22A) and $\log S^2 = 0.156 + 1.158 \log \bar{X}$ in PI (L) - 2 (Figure 22B) for adults of *H. vigintioctopunctata*.

The indices of aggregation were found to be greater than one in all the cases indicated that the aggregations were distributed in a clumped manner. The R^2 values (Table 23) indicated that 80.80 and 76.80 per cent variation in dispersion of adults in PI (L) - 1 and PI (L) - 2, respectively, could be explained by the Taylor's power law model.

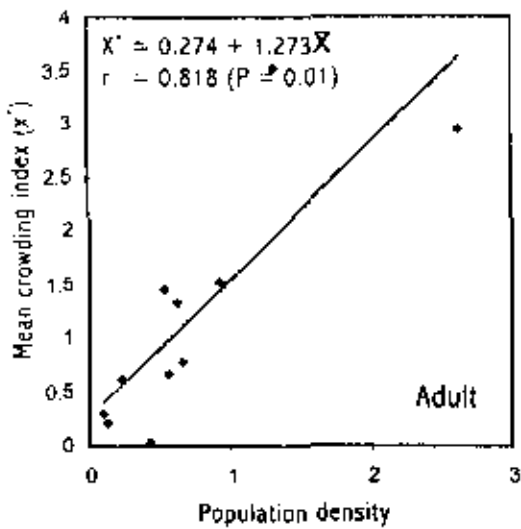


Fig. 21A

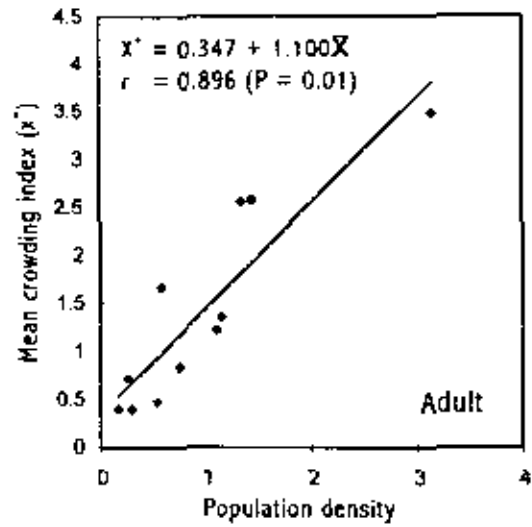


Fig. 21B

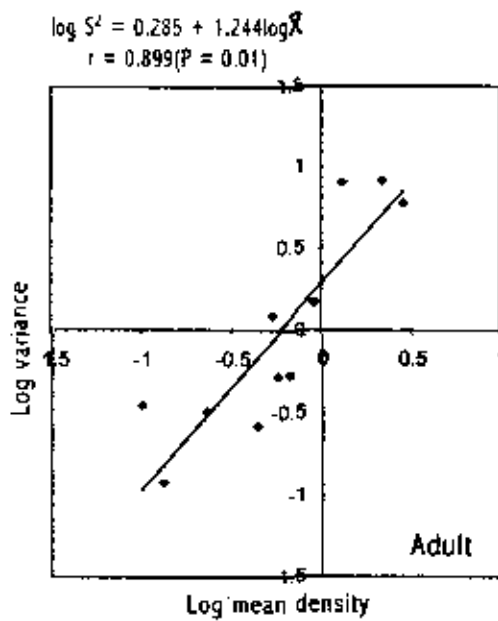


Fig. 22A

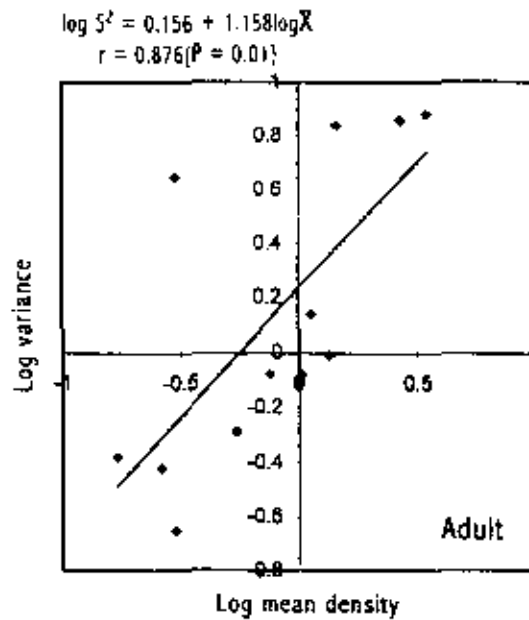


Fig. 22B

Fig. 21. Iwao's patchiness regressions of *H. vigintioctopunctata* adults (A, B) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1999-2000

Fig. 22. Taylor's power law regressions of *H. vigintioctopunctata* adults (A, B) on brinjal, under sampling methods PI(L)-1 and PI(L)-2, respectively, during 1999-2000

The values of F (Table 23) were found to be significant ($P = 0.01$) gave good fit of the model in all sampling methods.

4.9 Optimum sample number

The numbers of samples need to be sampled at a particular time would depend on expected densities of the insect population at different precision levels. The precision levels of 10 per cent and 25 per cent are considered as the standards for estimation of population density in relation to ecological studies and pest management studies, respectively.

4.9.1 Optimum sample numbers for *A. gossypii* nymphs and adults during 1998 – 99, using Plant Inspection Method

Table 29 shows the optimum sample numbers obtained by Ruesink's model (1980) at two levels of precision.

The optimum sample numbers for *A. gossypii* nymphs at 10 and 25 per cent precision levels were 38 and 32, and 6 and 5 for PI (A) – 1 and PI (A) – 2, respectively. While optimum sample numbers for adults were found to be 37 and 35 in PI (A) – 1 and PI (A) – 2, respectively. While optimum sample numbers of adults were found to be 37 and 35 in PI (A) – 1 and 6 and 5 in PI (A) – 2 method.

4.9.2 Optimum sample number for *A. gossypii* nymphs and adults during 1999 – 2000, using Plant Inspection Method

The optimum sample number calculated by using Ruesink's model for nymphs and adults are given in Table 30.

Table 29. Optimum sample numbers (Ruesink, 1980) for nymphs and adults of *A. gossypii* on brinjal during 1998-99

Sampling date	Sampling method	Optimum sample number (N)				
		Nymphs		Adults		
		C = 0.1	C = 0.25	C = 0.1	C = 0.25	
October	14	PI(A)-1	6	1	14	2
		PI(A)-2	7	1	30	5
	28	PI(A)-1	4	1	19	3
		PI(A)-2	7	1	41	6
November	11	PI(A)-1	16	3	32	5
		PI(A)-2	15	2	21	3
	25	PI(A)-1	27	4	66	11
		PI(A)-2	28	5	50	8
December	9	PI(A)-1	25	4	46	7
		PI(A)-2	23	4	71	11
	23	PI(A)-1	41	7	37	6
		PI(A)-2	54	9	31	5
January	7	PI(A)-1	19	3	52	8
		PI(A)-2	10	2	23	4
	21	PI(A)-1	6	1	12	2
		PI(A)-2	8	1	10	2
February	4	PI(A)-1	10	2	19	3
		PI(A)-2	13	2	15	2
	18	PI(A)-1	36	6	17	3
		PI(A)-2	24	4	22	4
March	4	PI(A)-1	68	11	61	10
		PI(A)-2	38	6	55	9
	18	PI(A)-1	29	5	39	6
		PI(A)-2	24	4	20	3
April	1	PI(A)-1	128	21	56	9
		PI(A)-2	42	7	39	6
	15	PI(A)-1	117	19	53	8
		PI(A)-2	151	26	61	10
Mean		PI(A)-1	38	6	37	6
		PI(A)-2	32	5	35	5

No. of samples (N) drawn :

in PI(A)-1 : 15

in PI(A)-2 : 10

C = 0.10 and C = 0.25 are precision levels

Table 30. Optimum sample numbers (Ruesink, 1980) for nymphs and adults of *A. gossypii* on brinjal during 1999-2000

Sampling date	Sampling method	Optimum sample number (N)				
		Nymphs		Adults		
		C = 0.1	C = 0.25	C = 0.1	C = 0.25	
November	11	PI(A)-1	74	12	71	11
		PI(A)-2	99	16	52	8
	25	PI(A)-1	56	9	22	4
		PI(A)-2	49	8	34	5
December	9	PI(A)-1	109	18	273	44
		PI(A)-2	150	24	235	38
	23	PI(A)-1	11	2	93	15
		PI(A)-2	62	10	73	12
January	6	PI(A)-1	255	41	246	41
		PI(A)-2	194	31	151	24
	20	PI(A)-1	95	15	172	28
		PI(A)-2	72	12	102	16
February	3	PI(A)-1	184	29	215	35
		PI(A)-2	191	31	89	14
	18	PI(A)-1	193	31	79	13
		PI(A)-2	190	30	197	31
March	2	PI(A)-1	241	38	99	16
		PI(A)-2	159	25	148	24
	17	PI(A)-1	86	14	66	11
		PI(A)-2	70	11	54	9
31	PI(A)-1	266	44	186	29	
	PI(A)-2	118	19	119	19	
April	14	PI(A)-1	-	-	567	85
		PI(A)-2	-	-	460	76
Mean	PI(A)-1	144	23	174	28	
	PI(A)-2	122	20	143	23	

No. of samples (N) drawn :

in PI(A)-1 : 15

in PI(A)-2 : 10

C = 0.10 and C = 0.25 are precision levels

The average sample numbers required to estimate nymphal population densities at 10 and 25 per cent precision levels were 144 and 122, and 23 and 20 for PI (A) – 1 and PI (A) – 2 respectively.

The optimum sample number for *A. gossypii* adults obtained at 10 and 25 per cent levels of precisions were 174 and 143, and 28 and 23 for PI (A) – 1 and PI (A) – 2, respectively.

4.9.3 Optimum sample numbers for *H. vigintioctopunctata* during 1998 – 99, using Plant Inspection Method

Data on optimum sample numbers calculated by Ruesink's model from two plant inspection methods at 10 and 25 per cent precision levels are presented in Table 31 and Table 32.

The average sample numbers obtained were 227 and 214 at 10 per cent precision level and 39 and 35 at 25 per cent level of egg cluster in PI (A) – 1 and PI (A) – 2 method, respectively.

The optimum sample numbers computed for adults at 10 and 25 per cent level of precisions were 191 and 130 and 30 and 21 in PI (A) – 1 and PI (A) – 2, respectively.

The sample numbers required for larvae at 10 and 25 per cent precision levels were 179 and 34 in PI (A) – 1 and 107 and 18 in PI (A) – 2, respectively.

The optimum number of samples needed to be sampled for pupae at 10 per cent precision levels were 241 in PI (A) – 1 and 140 in PI (A) – 2. Again at 25 per cent level, these were 35 in PI (A) – 1 and 22 in PI (A) – 2.

Table 31. Optimum sample numbers (Ruesink, 1980) for adults and egg clusters of *H. vigintioctopunctata* on brinjal during 1998-99

Sampling date	Sampling method	Optimum sample number (N)				
		Adults		Egg clusters		
		C = 0.1	C = 0.25	C = 0.1	C = 0.25	
October	14	PI(L)-1	139	23	0	0
		PI(L)-2	129	21	0	0
	28	PI(L)-1	100	16	0	0
		PI(L)-2	85	13	0	0
November	11	PI(L)-1	144	22	467	70
		PI(L)-2	200	32	500	80
	25	PI(L)-1	275	44	620	103
		PI(L)-2	171	27	414	64
December	9	PI(L)-1	242	39	0	0
		PI(L)-2	272	43	0	0
	23	PI(L)-1	511	77	0	0
		PI(L)-2	390	43	0	0
January	7	PI(L)-1	300	48	800	160
		PI(L)-2	84	14	667	100
	21	PI(L)-1	255	40	255	48
		PI(L)-2	109	24	217	35
February	4	PI(L)-1	84	14	147	24
		PI(L)-2	75	12	141	22
	18	PI(L)-1	115	18	187	29
		PI(L)-2	54	8	226	36
March	4	PI(L)-1	197	32	213	35
		PI(L)-2	51	8	64	10
	18	PI(L)-1	82	13	208	34
		PI(L)-2	23	4	132	21
April	1	PI(L)-1	11	2	192	31
		PI(L)-2	62	10	130	22
	16	PI(L)-1	219	35	90	15
		PI(L)-2	109	17	500	100
Mean	PI(L)-1	191	30	227	39	
	PI(L)-2	130	21	214	35	

No. of samples (N) drawn :

in PI(L)-1 : 30

in PI(L)-2 : 20

C = 0.10 and C = 0.25 are precision levels

Table 32. Optimum sample numbers (Ruesink, 1980) for larvae and pupae of *H. vigintioctopunctata* on brinjal during 1998-99

Sampling date	Sampling method	Optimum sample number (N)				
		Larvae		Pupae		
		C = 0.1	C = 0.25	C = 0.1	C = 0.25	
October	14	PI(L)-1	237	38	0	0
		PI(L)-2	103	19	0	0
	28	PI(L)-1	110	17	400	64
		PI(L)-2	83	13	186	29
November	11	PI(L)-1	172	28	181	29
		PI(L)-2	192	31	144	24
	25	PI(L)-1	189	30	436	69
		PI(L)-2	88	14	287	38
December	9	PI(L)-1	267	48	321	52
		PI(L)-2	196	32	270	43
	23	PI(L)-1	0	0	0	0
		PI(L)-2	0	0	0	0
January	7	PI(L)-1	0	0	0	0
		PI(L)-2	0	0	0	0
	21	PI(L)-1	281	43	0	0
		PI(L)-2	109	17	0	0
February	4	PI(L)-1	52	8	105	17
		PI(L)-2	30	5	63	10
	18	PI(L)-1	19	3	175	28
		PI(L)-2	21	3	48	8
March	4	PI(L)-1	18	3	102	16
		PI(L)-2	19	3	17	3
	18	PI(L)-1	169	27	112	18
		PI(L)-2	196	31	60	10
April	1	PI(L)-1	236	38	640	106
		PI(L)-2	131	21	261	40
	16	PI(L)-1	760	190	900	90
		PI(L)-2	333	57	625	100
Mean		PI(L)-1	179	34	241	35
		PI(L)-2	107	18	140	22

No. of samples (N) drawn :

in PI(L)-1 : 30

in PI(L)-2 : 20

C = 0.10 and C = 0.25 are precision levels

4.9.4 Optimum sample number for *H. vigintioctopunctata* during 1999 – 2000, using Plant Inspection Method

The results are summarized in Table 33 for egg clusters and adults, and Table 34 for larvae and pupae.

The optimum sample number calculated from Ruesink's model were 165 and 30 in PI (A) – 1 and 129 and 22 in PI (A) – 2, respectively at 10 and 25 per cent levels of precision for sampling egg clusters. In the case of adults, these were 378 and 64, and 262 and 42 in PI (A) – 1 and PI (A) – 2, respectively at these two levels of precision.

The average sample numbers required to estimate larval population at 10 and 25 per cent precision levels were 213 and 39, and 154 and 24 in PI (A) – 1 and PI (A) – 2, respectively. Similarly, the optimum sample numbers for pupae were found to be 191 and 34 in PI (A) – 1 and 146 and 26 in PI (A) – 2, respectively at 10 and 25 per cent levels of precision.

4.10 Varietal resistance

4.10.1 Infestation of *A. gossypii* on brinjal varieties

The intensity of attack and population density of *A. gossypii* on different varieties in field screening studies (1998 - 99) are presented in Table 35 and Table 36, respectively. Plate 21 shows the leaf infestation by *A. gossypii*.

Infestation of *A. gossypii* was recorded from third week of January (16 January), when all the varieties were infested and the intensity of attack ranged from 8.30 per cent leaf infestation in Aruna to 27.80 per cent leaf infestation in Pusa Uttam. Varietal effect

Table 33. Optimum sample numbers (Ruesink, 1980) for adults and egg clusters of *H. vigintioctopunctata* on brinjal during 1999-2000

Sampling date	Sampling method	Optimum sample number (N)			
		Adults		Egg clusters	
		C = 0.1	C = 0.25	C = 0.1	C = 0.25
November 25	PI(L)-1	640	107	325	65
	PI(L)-2	543	95	275	55
December 9	PI(L)-1	144	26	0	0
	PI(L)-2	170	27	0	0
23	PI(L)-1	1200	200	0	0
	PI(L)-2	700	105	0	0
January 6	PI(L)-1	700	140	0	0
	PI(L)-2	367	55	0	0
20	PI(L)-1	206	33	0	0
	PI(L)-2	94	15	0	0
February 3	PI(L)-1	340	54	255	42
	PI(L)-2	146	23	220	35
17	PI(L)-1	185	30	575	115
	PI(L)-2	166	27	412	66
March 2	PI(L)-1	175	29	238	39
	PI(L)-2	107	17	221	35
17	PI(L)-1	249	38	420	70
	PI(L)-2	147	24	287	46
31	PI(L)-1	50	8	0	0
	PI(L)-2	42	7	0	0
April 14	PI(L)-1	265	42	0	0
	PI(L)-2	403	64	0	0
Mean	PI(L)-1	378	64	165	30
	PI(L)-2	262	42	129	22

No. of samples (N) drawn :

in PI(L)-1 : 30

in PI(L)-2 : 20

C = 0.10 and C = 0.25 are precision levels

Table 34. Optimum sample numbers (Ruesink, 1980) for larvae and pupae of *H. vigintioctopunctata* on brinjal during 1999-2000

Sampling date	Sampling method	Optimum sample number (N)				
		Larvae		Pupae		
		C = 0.1	C = 0.25	C = 0.1	C = 0.25	
November 25	PI(L)-1	0	0	0	0	
	PI(L)-2	0	0	0	0	
December 9	PI(L)-1	139	19	0	0	
	PI(L)-2	91	15	0	0	
	23	PI(L)-1	675	135	1050	210
		PI(L)-2	537	86	675	135
January 6	PI(L)-1	0	0	0	0	
	PI(L)-2	0	0	0	0	
	20	PI(L)-1	0	0	0	0
		PI(L)-2	0	0	0	0
February 3	PI(L)-1	700	140	0	0	
	PI(L)-2	388	61	0	0	
	17	PI(L)-1	322	52	0	0
		PI(L)-2	273	42	0	0
March 2	PI(L)-1	225	36	260	41	
	PI(L)-2	218	35	262	42	
	17	PI(L)-1	146	23	254	40
		PI(L)-2	98	16	141	22
	31	PI(L)-1	139	22	124	20
		PI(L)-2	88	14	97	16
April 14	PI(L)-1	0	0	415	67	
	PI(L)-2	0	0	428	67	
Mean	PI(L)-1	213	39	191	34	
	PI(L)-2	154	24	146	26	

No. of samples (N) drawn :

in PI(L)-1 : 30

in PI(L)-2 : 20

C = 0.10 and C = 0.25 are precision levels

on intensity of attack was significant ($P = 0.01$) on 31 January. The lowest intensity (14.00%) was recorded on Aruna and the highest (38.90%) on Pusa Uttam, 'Kharua Bengena' and JC-2 also registered low intensity levels. However, the varieties in respect of intensity did not differ significantly in the rest of the sampling dates.

Seasonal mean intensities indicated that there were highly significant differences among the varieties. The seasonal mean intensity varied from 8.26 per cent in Aruna to 21.13 per cent in Neelam Long. 'Kharua Bengena' (local) registered comparatively lower infestation of 8.80 per cent, which was *at par* with Aruna. Variety Pusa Kranti, Pusa Bindu, AB-2, KS-331, Pant Samrat and Muktakeshi were *at par* in intensity of infestation which ranges from 12.32 to 14.06 per cent. Neelam Long was followed by Arka Keshav with 18.90 per cent intensity. However, non-significant ranges of moderate seasonal mean intensity (16.84 – 18.48%) were recorded on Pusa Uttam, Pusa Bhairav, Pusa Purple Long, Arka Nidhi, JC - 2 and 'Sagalisingia' (local).

The highest population densities of 2.96 aphids (nymph + adult)/leaf was obtained on JC-2 and the lowest of 0.23/leaf was recorded on 'Kharua Bengena' (local) on 16 January. On 31 January, aphid population densities were at peak in almost all the varieties with a level ranging between 2.11 (Aruna) to 8.06 (JC-2) per leaf. The lowest non-significant ranges of population density (2.11 to 2.25/leaf) were found in Aruna, KS-331 and 'Kharua Bengena', while the highest non-significant ranges (8.00 to 8.06/leaf) were found in JC-2 and Muktakeshi. There were highly significant ($P = 0.01$) differences in this regard among the varieties in all sampling dates except 1 April ($P = 0.05$). Comparison of seasonal mean density showed that Aruna with the lowest population

Table 35. Intensity of attack of *A. gossypii* on brinjal varieties

Variety	Date of observation and intensity of attack (% leaf infested)						*Seasonal mean
	16.1.99	31.1.99	15.2.99	2.3.99	17.3.99	1.4.99	
Pusa Kranti	16.70 (24.12)	19.40 (26.13)	14.00 (21.97)	11.10 (19.51)	11.10 (19.43)	8.30 (16.81)	13.28 (21.31)
Pusa Purple Long	22.20 (28.19)	30.50 (33.53)	16.70 (24.16)	11.10 (19.53)	19.40 (26.18)	11.10 (19.44)	18.09 (25.13)
Pusa Bindu	11.10 (19.48)	22.20 (28.13)	14.00 (21.97)	11.10 (19.46)	11.10 (19.50)	8.30 (16.71)	12.68 (20.86)
Pusa Uttam	27.80 (31.82)	38.90 (38.54)	16.70 (24.16)	11.10 (19.41)	14.00 (21.94)	11.10 (19.44)	16.84 (24.23)
Pusa Bhairav	25.00 (30.08)	33.30 (35.28)	19.40 (26.20)	14.00 (21.95)	11.10 (19.53)	8.30 (16.76)	17.70 (24.92)
AB-2	16.70 (24.15)	25.00 (30.04)	22.20 (28.14)	5.50 (13.52)	11.10 (19.48)	8.30 (16.75)	14.06 (21.99)
Aruna	8.30 (16.73)	14.00 (21.98)	14.00 (21.96)	2.70 (9.48)	8.30 (16.72)	5.50 (13.53)	8.26 (16.74)
KS-331	11.10 (19.44)	19.40 (26.15)	16.70 (24.16)	11.10 (19.47)	11.10 (19.43)	5.50 (13.59)	12.32 (20.36)
Pant Samrat	14.00 (21.93)	22.20 (28.14)	14.00 (21.95)	11.10 (19.46)	11.10 (19.49)	5.50 (13.60)	12.60 (20.75)
Arka Keshav	22.20 (28.13)	33.30 (35.26)	22.24 (28.10)	14.10 (21.91)	14.00 (21.98)	11.08 (19.50)	18.91 (25.81)
Arka Nidhi	22.24 (28.11)	38.28 (38.25)	19.43 (26.17)	11.10 (19.48)	14.05 (21.93)	8.32 (16.78)	18.04 (25.10)
Muktakeshi	14.10 (21.93)	25.00 (30.09)	14.13 (21.95)	8.28 (16.71)	8.33 (16.76)	8.31 (16.74)	12.46 (20.69)
Neelam Long	25.00 (30.11)	36.15 (36.95)	27.84 (31.86)	14.12 (21.93)	16.73 (24.15)	11.10 (19.43)	21.13 (27.38)
Kharua Bengena	8.33 (16.75)	14.18 (21.96)	14.09 (21.93)	8.27 (16.69)	8.35 (16.71)	2.70 (9.47)	8.80 (17.27)
JC-2	14.08 (21.90)	19.40 (26.14)	27.81 (31.84)	19.43 (26.16)	19.45 (26.18)	11.10 (19.51)	18.25 (25.27)
Sagalisingia	22.26 (28.12)	27.81 (31.80)	25.04 (30.00)	14.16 (21.92)	16.68 (24.15)	8.29 (16.75)	18.48 (25.46)
S.Ed.±	NS	2.215	NS	NS	NS	NS	1.522
CD(P=0.05)	-	4.52	-	-	-	-	3.034
CD(P=0.01)	-	6.07	-	-	-	-	4.037

Mean of 3 replications (3 plants/replication)

* Mean of data pertaining to 6 dates of observation. Figure in parentheses are angular values

Table 36. Population density of *A. gossypii* on brinjal varieties

Variety	Aphid population density (no./leaf)						*Seasonal mean
	16.1.99	31.1.99	15.2.99	2.3.99	17.3.99	1.4.99	
<i>Pusa Kranti</i>	0.83 (1.33)	6.22 (2.68)	2.41 (1.84)	0.80 (1.34)	1.28 (1.51)	0.87 (1.37)	2.07 (1.68)
<i>Pusa Purple Long</i>	2.67 (1.91)	7.17 (2.86)	3.20 (2.05)	1.87 (1.69)	1.49 (1.58)	0.91 (1.38)	2.88 (1.91)
<i>Pusa Bindu</i>	0.68 (1.28)	3.27 (2.07)	2.78 (1.94)	1.04 (1.43)	1.01 (1.42)	0.45 (1.19)	1.54 (1.56)
<i>Pusa Uttam</i>	1.97 (1.72)	6.12 (2.67)	2.76 (1.94)	1.30 (1.52)	1.72 (1.65)	0.77 (1.33)	2.44 (1.80)
<i>Pusa Bhairav</i>	2.05 (1.75)	6.25 (2.69)	2.72 (1.93)	0.30 (1.13)	1.36 (1.56)	0.76 (1.32)	2.24 (1.73)
AB-2	1.49 (1.58)	6.51 (2.74)	3.03 (2.00)	0.23 (1.09)	1.29 (1.51)	0.49 (1.21)	2.17 (1.69)
Aruna	0.43 (1.19)	2.11 (1.76)	2.53 (1.88)	0.24 (1.10)	1.22 (1.49)	0.14 (1.06)	1.11 (1.41)
KS-331	0.99 (1.41)	2.15 (1.77)	2.36 (1.83)	0.68 (1.29)	1.55 (1.59)	0.45 (1.19)	1.36 (1.52)
Pant Samrat	0.67 (1.27)	2.44 (1.86)	2.65 (1.91)	0.64 (1.28)	1.28 (1.51)	0.36 (1.16)	1.34 (1.50)
Arka Keshav	1.52 (1.59)	6.32 (2.71)	2.62 (1.90)	0.61 (1.27)	1.16 (1.47)	0.69 (1.30)	2.15 (1.71)
Arka Nidhi	1.42 (1.55)	5.23 (2.49)	2.33 (1.82)	1.20 (1.49)	1.40 (1.55)	0.39 (1.17)	1.99 (1.68)
<i>Muktakeshi</i>	2.42 (1.85)	8.00 (3.00)	3.20 (2.05)	1.36 (1.53)	1.83 (1.68)	0.78 (1.33)	2.93 (1.91)
Neelam Long	1.86 (1.69)	6.90 (2.81)	2.95 (1.99)	0.76 (1.31)	1.94 (1.71)	0.45 (1.19)	2.48 (1.78)
Kharua Bengena	0.23 (1.10)	2.25 (1.80)	2.18 (1.78)	1.00 (1.41)	1.08 (1.44)	0.16 (1.07)	1.15 (1.44)
JC-2	2.96 (1.98)	8.06 (3.01)	3.56 (2.13)	1.99 (1.73)	1.98 (1.73)	0.94 (1.39)	3.25 (1.99)
Sagalisingia	2.20 (1.78)	6.83 (2.79)	2.59 (1.89)	1.24 (1.49)	1.76 (1.66)	0.73 (1.32)	2.56 (1.82)
S.Ed.+	0.107	0.036	0.039	0.090	0.028	0.092	0.052
CD(P=0.05)	0.218	0.074	0.079	0.185	0.057	0.188	0.059
CD(P=0.01)	0.293	0.099	0.107	0.249	0.077	NS	0.078

Mean of 3 replications (3 plants/replication)

* Mean of data of each date. Figures in parentheses are $\sqrt{1+x}$ transformed values.

density of 1.11 aphids/leaf and 'Kharua Bengena' with 1.15 aphids/leaf were *at par* while JC-2 with a highest of 3.25 aphids/leaf significantly differed ($P = 0.01$) from other varieties. Varieties Pusa Purple Long and Muktakeshi (*at par*) followed by 'Sagalisingia' and Pusa Uttam (*at par*) registered higher seasonal mean population densities and varieties Pusa Bindu, KS-331 and Pant Samrat which were *at par* harboured comparatively low densities of *A. gossypii* population.

4.10.2 Infestation of *H. vigintioctopunctata* on brinjal varieties

Table 37 and Table 38 present the data on intensity of attack and population density respectively of *H. vigintioctopunctata* on brinjal varieties. Plate 22 and 23 shows the leaf infestation by larvae and adult, respectively. Initially, the intensity of infestation was low, ranging from 3.20 per cent infested plants in Arka Keshav to 32.50 per cent infested plants in Pusa Bindu on 7 February. No infestation was recorded on Aruna, KS-331, 'Kharua Bengena' and 'Sagalisingia' on 7 February. Intensity of attack on different varieties as recorded on this date did not differ significantly. The intensity increased in most of the varieties when counts were taken after two weeks *i.e.*, on 21 February, where Pusa Bindu suffered the attack at peak intensity (79.50%) while 'Kharua Bengena' suffered only 2.30 per cent. There were highly significant ($P = 0.01$) differences among varieties with regards to intensity of attack on this date. Varieties Sagalisingia, Pusa Kranti, Aruna, KS-331, Pant Samrat, Arka Keshav and Muktakeshi were *at par* (at $P = 0.01$) registering 4.80 to 15.30 per cent attack by the beetles; whereas, JC-2, Pusa Purple Long and Pusa Uttam suffered comparatively higher intensities with a range of 47.30 to 49.40 per cent. On 7 March, the intensity of infestation was at peak on

Table 37. Intensity of attack of *H. vigintioctopunctata* on brinjal varieties

Variety	Date of observation and intensity of attack (% leaf infested)						Seasonal mean
	7.2.99	21.2.99	7.3.99	21.3.99	5.4.99	20.4.99	
Pusa Kranti	10.30 (18.75)	13.90 (21.91)	32.20 (34.54)	11.10 (19.49)	5.60 (13.70)	9.00 (17.45)	12.84 (20.96)
Pusa Purple Long	25.60 (30.42)	47.30 (43.43)	69.10 (56.25)	30.80 (33.74)	13.90 (21.86)	15.90 (23.50)	32.63 (34.86)
Pusa Bindu	32.50 (34.78)	79.50 (63.10)	60.60 (51.14)	32.50 (34.72)	9.00 (17.49)	20.40 (26.83)	38.03 (38.00)
Pusa Uttam	20.40 (26.82)	48.90 (44.37)	76.70 (61.15)	31.63 (34.20)	12.70 (20.89)	21.50 (27.62)	34.28 (35.84)
Pusa Bhairav	16.50 (23.98)	22.20 (27.95)	62.80 (52.43)	28.50 (32.28)	12.30 (20.51)	18.80 (25.68)	25.70 (30.47)
AB-2	5.40 (13.44)	19.20 (25.96)	45.60 (42.50)	28.80 (32.47)	7.80 (16.23)	12.60 (20.80)	18.16 (25.23)
Aruna	0.00 (0.08)	10.70 (19.06)	15.80 (23.43)	13.30 (21.40)	3.70 (11.12)	0.00 (0.08)	4.78 (12.52)
KS-331	0.00 (0.08)	15.30 (23.03)	26.40 (30.89)	13.40 (21.44)	5.80 (13.92)	10.60 (19.05)	9.66 (18.07)
Pant Samrat	8.80 (17.28)	11.00 (19.36)	38.90 (38.57)	11.40 (19.75)	5.60 (13.70)	0.00 (0.08)	9.68 (18.12)
Arka Keshav	3.20 (10.32)	14.00 (21.95)	30.70 (33.63)	7.20 (15.58)	4.80 (12.67)	6.30 (14.54)	9.62 (18.11)
Arka Nidhi	5.50 (13.56)	28.00 (31.92)	45.30 (42.28)	19.20 (25.96)	8.28 (16.76)	9.20 (17.67)	17.48 (24.70)
Muktakeshi	13.20 (21.32)	15.00 (22.80)	66.30 (54.54)	26.50 (30.96)	2.00 (8.16)	0.00 (0.08)	15.24 (22.96)
Neelam Long	10.70 (19.08)	28.40 (32.22)	59.10 (50.25)	25.70 (30.47)	10.80 (19.20)	4.60 (12.38)	21.00 (27.26)
Kharua Bengena	0.00 (0.08)	2.30 (8.74)	13.50 (21.55)	3.50 (10.76)	2.80 (9.63)	2.10 (8.34)	2.96 (9.85)
JC-2	8.80 (17.28)	49.40 (44.62)	68.40 (55.76)	24.60 (29.79)	7.80 (16.25)	15.30 (23.03)	26.63 (31.11)
Sagalisingia	0.00 (0.08)	4.80 (12.65)	15.70 (23.34)	6.30 (14.57)	3.70 (11.07)	0.00 (0.08)	3.20 (10.30)
S.Ed±	NS	5.350	4.640	NS	NS	NS	3.594
CD(P=0.05)	-	10.910	9.483	-	-	-	7.163
CD(P=0.01)	-	14.661	12.742	-	-	-	9.531

Mean of 3 replications (3 plants/replication)

* Mean of data pertaining to 6 dates of observation. Figure in parentheses are angular values

most of the varieties ranging from 13.50 per cent in 'Kharua Bengena' to 76.70 per cent in Pusa Uttam. On this date also, varieties showed highly significant differences ($P = 0.01$). Varieties showing least intensity of attack were 'Sagalisingia' (15.70 %) and Aruna (15.80%), which were *at par* with 'Kharua Bengena'. Varieties with comparatively high intensity of attack were Pusa Purple Long, Pusa Bindu, Pusa Bhairav, Muktakeshi, Neelam Long and JC-2, which registered intensities of more than 59.10 per cent. The intensity of attack decreased thereafter. No significant differences occurred among varieties in this respect from the next sampling occasion onwards. Seasonal mean intensity was highest (38.03%) in Pusa Bindu and lowest (2.96%) in 'Kharua Bengena'. The lowest values of non-significant range of seasonal mean intensity was 2.96 to 9.68 per cent which included varieties 'Sagalisingia', Arka Keshav, Pant Samrat, KS-331, Aruna and 'Kharua Bengena'. The highest non-significant range was 25.70 to 38.03 per cent seasonal mean intensity obtained in varieties JC-2, Pusa Bhairav, Pusa Uttam, Pusa Purple Long and Pusa Bindu.

Population density of *H. vigintioctopunctata* was recorded on brinjal varieties from 7 February. The highest density of 4.07 beetles/branch and lowest of 0.12 beetles/branch were recorded on JC-2 and Arka Keshav, respectively on this date. However, no population was observed on Aruna, KS-331, 'Kharua Bengena' and 'Sagalisingia'. There were highly significant differences among varieties with regards to population densities. The population data on the next sampling date showed the highest population of 14.56 beetles/branch in Pusa Bindu followed by Pusa Purple Long (8.47/branch), Pusa Uttam (7.99/branch) and JC-2 (6.61/branch) and the lowest

Table 38. Population density of *H. vigintioctopunctata* on brinjal varieties

Variety	<i>H. vigintioctopunctata</i> population density (no./branch)						Mean
	7.2.99	21.2.99	7.3.99	21.3.99	5.4.99	20.4.99	
Pusa Kranti	1.47 (1.56)	1.51 (1.58)	5.79 (2.60)	1.19 (1.48)	0.45 (1.20)	1.36 (1.53)	1.96 (1.66)
Pusa Purple Long	3.13 (2.03)	8.47 (3.08)	14.10 (3.88)	5.64 (2.56)	1.92 (1.70)	3.31 (2.07)	6.09 (2.55)
Pusa Bindu	3.54 (2.13)	14.56 (3.94)	10.13 (3.33)	4.31 (2.30)	0.93 (1.38)	2.62 (1.90)	6.01 (2.50)
Pusa Uttam	2.91 (1.97)	7.99 (2.99)	11.77 (3.56)	4.86 (2.42)	1.32 (1.52)	3.14 (2.03)	5.33 (2.42)
Pusa Bhairav	2.15 (1.77)	4.31 (2.30)	8.92 (3.14)	4.54 (2.35)	2.38 (1.84)	2.77 (1.94)	4.18 (2.22)
AB-2	0.29 (1.13)	2.06 (1.74)	6.43 (2.72)	3.37 (2.09)	0.93 (1.38)	1.60 (1.61)	2.45 (1.78)
Aruna	0.00 (1.00)	1.40 (1.54)	4.03 (2.24)	2.67 (1.91)	0.32 (1.14)	0.00 (1.00)	1.40 (1.47)
KS-331	0.00 (1.00)	1.73 (1.64)	4.52 (2.35)	1.56 (1.55)	0.41 (1.18)	1.25 (1.46)	1.58 (1.53)
Pant Samrat	0.73 (1.32)	0.93 (1.390)	6.87 (2.80)	1.32 (1.52)	0.54 (1.24)	0.00 (1.00)	1.73 (1.54)
Arka Keshav	0.12 (1.05)	2.74 (1.93)	7.32 (2.87)	3.77 (2.18)	0.88 (1.37)	1.95 (1.71)	2.80 (1.85)
Arka Nidhi	0.43 (1.19)	3.87 (2.21)	7.96 (2.99)	3.40 (2.09)	1.05 (1.40)	1.28 (1.51)	2.99 (1.89)
Muktakeshi	0.74 (1.32)	1.06 (1.43)	5.89 (2.62)	2.66 (1.91)	0.40 (1.16)	0.00 (1.00)	1.79 (1.57)
Neelam Long	1.88 (1.69)	3.94 (2.22)	9.58 (3.25)	4.09 (2.25)	1.08 (1.41)	0.66 (1.27)	3.54 (2.02)
Kharua Bengena	0.00 (1.00)	0.41 (1.18)	3.65 (2.15)	0.56 (1.24)	0.51 (1.22)	0.73 (1.29)	0.98 (1.35)
JC-2	4.07 (2.25)	6.61 (2.75)	12.53 (3.67)	3.97 (2.22)	1.27 (1.50)	2.17 (1.78)	5.10 (2.36)
Sagalisingia	0.00 (1.00)	1.55 (1.59)	7.12 (2.85)	2.04 (1.73)	0.61 (1.26)	0.00 (1.00)	1.89 (1.57)
S.Ed.±	0.086	0.128	0.156	0.182	0.162	0.148	0.102
CD(P=0.05)	0.176	0.263	0.319	0.372	0.332	0.302	0.116
CD(P=0.01)	0.237	0.354	0.429	0.500	0.447	0.407	0.154

Mean of 3 replications (3 plants/replication)

* Mean of data of each date. Figure in parentheses are $\sqrt{1+x}$ transformed values

population of 0.41 beetles/branch in 'Kharua Bengena'. The peak population density for most of the varieties were attained on 7 March. The highest peak of 14.10 beetles/branch was obtained on Pusa Purple Long and lowest peak was registered by 'Kharua Bengena' with a population density of 3.65 beetles/branch. However, Pusa Bindu exhibited the highest population density of 14.65/branch on the last sampling date. The population of *H. vigintioctopunctata* started decreasing after attainment of peak in each successive sampling and reached their lowest level during the first week of April (5 April) and again increased slightly in some varieties. The population density of the phytophagous coccinellids in different brinjal varieties differed significantly in all sampling dates at 1 per cent probability level. The seasonal mean comparison of population densities among varieties of brinjal showed highly significant differences at $P = 0.01$. Varieties Pusa Purple Long and Pusa Bindu were most susceptible among the varieties showing high seasonal mean densities of 6.09 and 6.01 beetles per branch, respectively and the only least susceptible variety 'Kharua Bengena' carried a seasonal mean density of 0.98 beetles/branch, which was significantly different from all other varieties. Varieties Aruna, KS-331, Pant Samrat, 'Sagalisingia' and Muktakeshi harboured comparatively low densities, while Pusa Uttam and JC-2 harboured comparatively high densities of *H. vigintioctopunctata*.

4.11 Ranking of brinjal varieties for resistance/susceptibility

Ranking of brinjal varieties for resistance/susceptibility was done for *A. gossypii* and *H. vigintioctopunctata* based on their population density. Infestation parameters such as intensity of attack and population density exhibited significant differences among

brinjal varieties for both the pest species. Out of these two infestation parameters, pest population density was chosen as a basis for ranking varieties, because of its better precisions than intensity as the latter gives only an idea of the proportion of leaves attacked but no quantification of the damaging population on the sampled leaves/branch. Hence, ranking was done in terms of population density for both *A. gossypii* (no. of aphids/leaf) and *H. vigintioctopunctata* (no. of beetles/branch).

4.11.1 Varietal ranking based on *A. gossypii* population

Ranking of brinjal varieties against *A. gossypii* is presented in Table 39. None of the 16 varieties could be ranked as highly resistant or highly susceptible. Only two varieties were found to be resistant, namely Aruna and 'Kharua Bengena' (local). Moderately resistant varieties were Pant Samrat, KS-331 and Pusa Bindu. Varieties Arka Nidhi, Pusa Kranti, AB-2, Arka Keshav and Pusa Bhairav were ranked as moderately susceptible and rest of the varieties were susceptible to *A. gossypii*.

4.11.2 Varietal ranking based on *H. vigintioctopunctata* population

Table 40 shows the ranking of brinjal varieties against *H. vigintioctopunctata*. None of the varieties tested could be ranked as highly resistant or highly susceptible. Out of the 16 varieties, only 'Kharua Bengena' (local) was found to be resistant against *H. vigintioctopunctata*. Six of the varieties namely, Aruna, KS-331, Pant Samrat, 'Sagalisingia' (local), Muktakeshi and Pusa Kranti were found to be moderately resistant. Varieties AB-2, Arka Keshav, Arka Nidhi and Neelam Long were ranked as moderately susceptible and remaining varieties were susceptible to *H. vigintioctopunctata*.

Table 39. Ranking of brinjal varieties based on population density of *A. gossypii*

Rank	Population density (no. of aphids/leaf)	Variety
Highly resistant	≤ 1	-
Resistant	$>1 - \leq 1.2$	Aruna, "Kharua Bengena"
Moderately resistant	$>1.2 - \leq 1.6$	Pant Samrat, KS-331, Pusa Bindu
Moderately susceptible	$>1.6 - \leq 2.4$	Arka Nidhi, Pusa Kranti, AB-2, Arka Keshav, Pusa Bhairav
Susceptible	$>2.4 - \leq 4$	Neelam Long, Pusa Uttam, "Sagalisingia", Muktakeshi, Pusa Purple Long, JC-2
Highly susceptible	>4	-

Table 40. Ranking of brinjal varieties based on population density of *H. vigintioctopunctata*

Rank	Population density (no. of beetles/branch)	Variety
Highly resistant	≤ 0.5	-
Resistant	$>0.5 - \leq 1$	"Kharua Bengena"
Moderately resistant	$>1 - \leq 2$	Aruna, KS-331, Pant Samrat, Sagalisingia", Muktakeshi, Pusa Kranti
Moderately susceptible	$>2 - \leq 4$	AB-2, Arka Keshav, Arka Nidhi, Neelam Long
Susceptible	$>4 - \leq 8$	Pusa Bhairav, JC-2, Pusa Uttam, Pusa Bindu, Pusa Purple Long
Highly susceptible	>8	-

4.12 Varietal effect on certain biological parameters of *A gossypii*

Laboratory biology of *A. gossypii* on different brinjal varieties to determine the effect of the varieties on nymphal period nymphal survival, adult longevity, total life span, reproductive period, fecundity and rate of nymphal deposition, which are presented in Table 41 and 42.

4.12.1 Effect of varieties on development parameters

Table 41 presents the data on nymphal period, nymphal survival, adult longevity and total life span of *A. gossypii* on different brinjal varieties. The data clearly indicated that brinjal varieties significantly affected the nymphal period of *A. gossypii*. It was also evident from the data that the differences ($P = 0.01$) in total nymphal period among varieties were greatly influenced by the differences ($P = 0.01$) in first instar durations, which lasted as long as 2.78 days in Aruna and as short as 1.92 days in Muktakeshi. Varieties did not differ significantly in respect of the durations of other nymphal instars. The total nymphal period of the aphid was shortest (6.99 days) on JC-2, which was *at par* with AB-2, 'Sagalisingia', Pusa Purple Long, Pusa Bhairav, Neelam Long, Pusa Uttam, Muktakeshi, Arka Keshav and Pusa Kranti. Whereas the period was longest (8.31 days) on 'Kharua Bengena' followed by Aruna (8.09 days) and Pant Samrat (8.05 days).

The nymphal survival was maximum (95.83%) when reared on JC-2 and was minimum (50.00%) when reared on 'Kharua Bengena'. There was a highly significant effect ($P = 0.01$) of the varieties on the nymphal survival of the aphid. A non-significant range of 83.33 to 91.60 per cent nymphal survival was obtained on varieties 'Sagalisingia' (91.60 %), Neelam Long (87.50%), Arka Keshav (83.33 %), AB-2

Table 41. Duration of developmental stages of *A. gossypii* on brinjal varieties

Variety	Nymphal period (days)				Total nymphal period (days)	*Nymphal survival (%)	Total longevity (days)	Total life span (days)
	Instar I	Instar II	Instar III	Instar IV				
Pusa Kranti	2.15±0.06	1.98±0.11	1.50±0.07	1.58±0.04	7.32±0.28	75.00 (60.06)	12.03±0.58	19.45±1.07
Pusa Purple Long	2.06±0.09	1.83±0.08	1.50±0.06	1.63±0.06	7.13±0.21	91.60 (73.32)	11.90±0.55	19.13±0.98
Pusa Bindu	2.18±0.14	1.95±0.07	1.62±0.06	1.66±0.08	7.58±0.32	75.00 (60.03)	12.00±0.64	19.57±1.01
Pusa Uttam	2.08±0.08	1.96±0.06	1.56±0.09	1.75±0.07	7.20±0.19	87.50 (69.51)	11.99±0.61	19.28±0.85
Pusa Bhairav	1.98±0.06	1.85±0.08	1.60±0.04	1.66±0.09	7.15±0.25	83.33 (66.03)	12.08±0.72	19.20±1.13
AB-2	2.00±0.00	1.92±0.06	1.56±0.08	1.62±0.06	7.06±0.18	91.60 (76.19)	11.99±0.50	19.12±1.08
Aruna	2.78±0.06	2.00±0.00	1.66±0.05	1.70±0.09	8.09±0.34	54.16 (47.41)	11.80±0.68	20.08±1.68
KS-331	2.48±0.05	2.08±0.10	1.63±0.02	1.66±0.04	7.87±0.23	66.83 (54.90)	12.10±0.52	19.93±0.93
Pant Samrat	2.50±0.07	1.98±0.16	1.92±0.11	1.80±0.10	8.05±0.31	54.16 (47.42)	12.00±0.73	20.36±1.26
Arka Keshav	2.15±0.11	1.87±0.15	1.80±0.09	1.70±0.08	7.31±0.26	83.33 (67.05)	12.05±0.82	19.43±1.05
Arka Nidhi	2.17±0.09	1.92±0.08	1.75±0.06	1.75±0.06	7.65±0.32	79.16 (63.19)	11.90±0.61	19.67±1.17
Muktakeshi	1.92±0.13	1.85±0.08	1.75±0.05	1.80±0.09	7.25±0.19	83.33 (66.44)	11.85±0.70	19.21±0.78
Neelam Long	1.95±0.12	1.81±0.09	1.62±0.06	1.75±0.00	7.19±0.16	87.50 (72.96)	12.28±0.89	19.55±1.12
Kharua Bengena	2.55±0.09	2.17±0.08	1.87±0.04	1.80±0.08	8.31±0.39	50.00 (45.00)	11.80±0.76	20.62±1.49
JC-2	2.00±0.00	1.75±0.07	1.66±0.08	1.62±0.09	6.99±0.22	95.83 (83.10)	12.66±0.61	19.58±1.32
Sagalisingia	2.17±0.08	1.82±0.05	1.58±0.08	1.58±0.10	7.07±0.24	91.60 (76.16)	12.40±0.67	19.51±1.18
S.E.d±	0.14	-	-	-	0.17	6.00	-	-
C.D(P=0.05)	0.30	NS	NS	NS	0.35	12.25	NS	NS
C.D(P=0.01)	0.40	NS	NS	NS	0.48	16.50	NS	NS

Mean of 24 individuals from two successive generations

*Figure in parentheses are angular values

(91.60%), Pusa Uttam (87.50%) and Pusa Purple Long (91.60%) at 1 per cent probability level. Another non-significant range (50.00 - 75.00 %) from the lowest order of nymphal survival were registered by varieties, Pusa Kranti, Pusa Bindu, Aruna, KS-331 and Pant Samrat, which were *at par* with 'Kharua Bengena'.

The data on adult longevity of *A. gossypii* was however, not significantly affected by the varieties. Aphids reared on JC-2 registered the longest adult life (12.66 days) and those reared on 'Kharua Bengena' and Aruna accounted for the shortest adult longevity (11.80 days). Similarly, the data representing total life span of *A. gossypii* on different varieties did not differ significantly. The longest total life span (20.62 days) was recorded on 'Kharua Bengena' and the shortest (19.12 days) on AB-2.

4.12.2 Effect of varieties on reproductive parameters

Data on reproductive parameters are presented in Table 42. The pre-reproductive period varied from 0.50 to 1.08 days. Highly significant ($P = 0.01$) differences existed among the varieties in this respect. The varieties Aruna, KS-331 and Pant Samrat with 1.00 day each and variety 'Kharua Bengena' with 1.08 days were significantly different ($P = 0.01$) from the rest in respect of pre-reproductive period of *A. gossypii*. The reproductive and post-reproductive period of the aphid did not show any significant differences among varieties. The reproductive period was longest (11.12 days) on JC-2 and shortest (9.95 days) on 'Kharua Bengena'. The post reproductive period ranged between 0.75 days in 'Kharua Bengena' to 0.90 days in Pant Samrat. The fecundity observed were highest (54.48 nymphs/female) on JC-2 and lowest (31.80 nymphs/female) on 'Kharua Bengena'. However, the varieties did not significantly differ

Table 42. Reproductive parameters of *A. gossypii* on brinjal varieties

Variety	Pre-reproductive period (days)	Reproductive period (days)	Post-reproductive period (days)	Fecundity (no. of nymphs per female)	Reproductive rate (No. of nymphs/female/day)
Pusa Kranti	0.75±0.08	10.48±0.06	0.80±0.03	42.44±4.39	4.05±0.09
Pusa Purple Long	0.50±0.04	10.56±0.45	0.85±0.05	51.15±7.41	4.81±0.13
Pusa Bindu	0.83±0.07	10.40±0.21	0.80±0.02	41.50±3.94	4.07±0.08
Pusa Utam	0.58±0.06	10.58±0.26	0.83±0.03	44.80±4.16	4.36±0.14
Pusa Bhairav	0.58±0.06	10.50±0.37	0.85±0.03	47.91±4.41	4.52±0.19
AB-2	0.50±0.00	10.61±0.79	0.88±0.05	49.75±5.21	4.66±0.16
Aruna	1.00±0.08	9.98±0.52	0.83±0.04	33.26±3.62	3.30±0.08
KS-331	1.00±0.09	10.20±0.67	0.80±0.03	42.33±3.65	4.20±0.08
Pant Samrat	1.00±0.08	10.10±0.81	0.90±0.05	39.40±3.63	3.92±0.07
Arka Keshav	0.75±0.00	10.50±0.75	0.78±0.04	44.10±3.18	4.26±0.18
Arka Nidhi	0.83±0.04	10.24±0.58	0.86±0.04	43.44±3.59	4.23±0.21
Muktakeshi	0.66±0.05	10.42±0.93	0.80±0.03	44.80±4.05	4.34±0.32
Neelam Long	0.58±0.05	10.81±0.74	0.85±0.04	47.02±5.18	4.40±0.17
Kharua Bengena	1.08±0.07	9.95±0.68	0.75±0.03	31.80±3.26	3.18±0.09
JC-2	0.50±0.06	11.12±0.53	0.84±0.03	54.48±7.22	4.98±0.38
Sagalisingia	0.50±0.04	11.08±0.60	0.86±0.04	51.85±6.38	4.78±0.29
S.Ed±	0.15	-	-	-	0.39
CD(P=0.05)	0.30	NS	NS	NS	0.81
CD(P=0.01)	0.41	NS	NS	NS	1.09

Mean of 24 individuals from two successive generations

in this regard. Aphids showed marked variation in reproductive rate when reared on different brinjal varieties. The maximum reproductive rate was observed on JC-2 (4.98 nymphs/female/day) followed by Pusa Purple Long (4.81 nymphs/female/day) and 'Sagalisingia' (4.78 nymphs/female/day) and minimum on 'Kharua Bengena' (3.18 nymphs/female/day) followed by Aruna (3.30 nymphs/female/day) and Pant Samrat (3.92 nymphs/female/day). Pusa Bindu (4.07 nymphs/female/day) also registered comparatively lower rates of reproduction.

4.13 Varietal effect on biological parameters of *H. vigintioctopunctata*

Laboratory studies pertaining to the comparative biology of *H. vigintioctopunctata* on different brinjal varieties were made to ascertain its possible effects on biological parameters. Table 43 to 46 show the data on relevant parameters.

4.13.1 Effect of varieties on developmental parameters

The data on incubation period, larval period and pupal period of *H. vigintioctopunctata* on different brinjal varieties are presented in Table 43. It is apparent from the data that brinjal varieties significantly influenced on the developmental periods of egg, larva and pupa. The incubation period was maximum (5.00 days) in variety Aruna and minimum (3.26 days) in Pusa Bindu. The incubation periods recorded on Pusa Purple Long, Pusa Bhairav, Arka Nidhi, Neelam Long and JC-2 were comparatively shorter (3.86 to 4.06 days) which were statistically *at par*. In all other varieties, the incubation period was longer (4.26 to 4.93 days). Significant differences ($p = 0.01$) were also found among varieties in respect of durations of all the larval instars and total larval period of *H. vigintioctopunctata*. The total larval period of 21.63 days

Table 43. Duration of developmental stages of *H. vigintioctopunctata* on brinjal varieties

Variety	Incubation period (days)	Larval period (days)				Total larval period (days)	Pupal period (days)
		Instar I	Instar II	Instar III	Instar IV		
Pusa Kranti	4.26±0.18	5.91±0.16	5.28±0.14	3.95±0.12	6.11±0.34	21.25±0.89	5.05±0.32
Pusa Purple Long	3.46±0.12	4.80±0.07	3.98±0.22	3.21±0.24	4.20±0.29	16.19±0.93	5.17±0.45
Pusa Bindu	3.26±0.03	4.45±0.15	4.08±0.12	3.06±0.33	3.43±0.26	15.02±0.78	5.07±0.65
Pusa Uttam	4.66±0.04	5.56±0.08	5.02±0.10	3.30±0.12	4.07±0.34	17.95±0.82	5.16±0.46
Pusa Bhairav	3.86±0.06	4.93±0.13	5.68±0.13	3.15±0.13	4.93±0.15	18.69±0.65	5.02±0.31
AB-2	4.40±0.02	5.86±0.13	5.22±0.33	4.22±0.09	4.77±0.66	20.06±1.02	5.09±0.18
Aruna	5.00±0.13	5.66±0.21	6.44±0.28	3.72±0.08	4.83±0.46	20.65±0.91	5.44±0.28
KS-331	4.93±0.06	5.88±0.08	5.18±0.14	4.11±0.12	4.33±0.16	19.48±0.79	5.26±0.35
Pant Samrat	4.73±0.16	5.70±0.11	5.19±0.23	4.93±0.13	5.82±0.54	21.63±0.98	5.18±0.29
Arka Keshav	4.35±0.08	5.30±0.07	6.08±0.35	4.16±0.22	4.58±0.19	20.06±0.85	4.50±0.17
Arka Nidhi	3.89±0.09	5.71±0.10	5.66±0.15	4.15±0.13	4.48±0.64	20.00±0.88	5.08±0.12
Muktakeshi	4.48±0.13	5.78±0.03	4.78±0.13	4.05±0.08	6.41±0.11	21.02±0.46	5.30±0.23
Neelam Long	4.00±0.04	5.75±0.10	4.00±0.12	3.83±0.18	4.08±0.64	17.66±0.94	4.80±0.28
Kharua Bengena	4.46±0.11	6.11±0.08	5.16±0.32	4.39±0.15	5.83±0.44	21.49±1.06	5.48±0.65
JC-2	4.06±0.15	5.10±0.02	4.00±0.19	4.08±0.23	4.50±0.36	17.69±0.73	5.16±0.44
Sagalisingia	4.57±0.02	5.92±0.04	4.36±0.16	4.27±0.17	5.05±0.11	19.60±0.90	4.55±0.17
S.Ed±	0.33	0.37	0.23	0.18	0.25	0.72	0.15
CD(P=0.05)	0.66	0.75	0.47	0.37	0.51	1.48	0.30
CD(P=0.01)	0.89	1.02	0.63	0.50	0.68	1.99	0.41

Mean of 15 individuals from one generation

recorded on the variety Pant Samrat was the maximum and 15.02 days in Pusa Bindu was the minimum. The larval period recorded on Pusa Purple Long (16.19 days) was comparatively shorter which was *at par* with Neelam Long (17.66 days) and JC-2 (17.69 days). The larvae took comparatively longer periods for development on 'Kharua Bengena' (21.49 days), Pusa Kranti (21.25 days), Muktakeshi (21.02 days) and Aruna (20.65 days). As regards to pupal period, the varieties 'Kharua Bengena' and Arka Keshav registered the longest (5.48 days) and shortest (4.50 days), respectively. Statistical analysis indicated significant difference among the varieties in respect of pupal period. Varieties 'Sagalisingia' (4.55 days) and Neelam Long (4.80 days) exhibited comparatively shorter pupal periods, whereas Muktakeshi (5.30 days), KS-331 (5.26 days) and Pant Samrat (5.18 days) showed comparatively longer pupal periods.

The data on egg hatchability, larval survival, adult emergence and growth index of *H. vigintioctopunctata* on different brinjal varieties are presented in Table 44. The maximum per cent egg hatchability (88.50%) was observed on Arka Keshav and the minimum percentage (56.00%) was on 'Kharua Bengena'. There was significant difference ($P = 0.01$) among varieties in respect of per cent hatching of eggs. Significant differences ($P = 0.01$) existed among them in respect of larval survival of *H. vigintioctopunctata*. A maximum of 93.30 per cent larvae survived and entered pupation when they were allowed to feed on Pusa Utam, Arka Nidhi, and Pusa Purple Long which were *at par* with Pusa Bindu (92.50 %), while only 46.60 per cent larvae could survive when they were offered to feed on Aruna which was statistically not different from KS - 331 and 'Kharua Bengena'. A maximum of 92.40 per cent adult emergence was

Table 44. Hatchability, larval survival, adult emergence and growth index of *H. vingintioctopunctata* on brinjal varieties

Variety	¹ Hatchability (%)	² Larval survival (%)	³ Adult emergence (%)	² Growth index
Pusa Kranti	60.00 (50.77)	73.30 (59.03)	85.50 (67.76)	3.46
Pusa Purple Long	82.00 (65.10)	93.40 (75.32)	92.10 (73.82)	5.78
Pusa Bindu	75.00 (60.15)	92.50 (74.24)	92.40 (74.06)	6.17
Pusa Uttam	78.00 (62.16)	93.30 (75.61)	91.60 (73.40)	5.20
Pusa Bhairav	84.00 (66.56)	86.60 (68.69)	84.60 (66.99)	4.64
AB-2	68.00 (55.71)	60.00 (50.82)	62.50 (52.25)	2.99
Aruna	62.50 (52.31)	46.60 (43.04)	75.00 (58.94)	2.26
KS-331	73.00 (58.81)	47.50 (43.55)	87.50 (69.70)	2.43
Pant Samrat	81.25 (63.71)	73.30 (59.01)	80.00 (63.49)	3.39
Arka Keshav	88.50 (70.65)	80.00 (63.60)	91.65 (73.50)	3.98
Arka Nidhi	86.00 (68.20)	93.30 (75.43)	92.30 (74.74)	4.67
Muktakeshi	79.75 (63.10)	66.60 (54.76)	87.50 (69.38)	3.17
Neelam Long	86.50 (68.47)	80.00 (63.52)	90.90 (72.68)	4.56
Kharua Bengana	56.00 (48.52)	53.30 (46.89)	71.40 (57.80)	2.48
JC-2	80.00 (63.49)	80.00 (63.49)	81.80 (64.75)	4.53
Sagalisingia	71.00 (57.51)	73.30 (58.90)	66.60 (54.77)	3.74
S.E.M	3.472	2.556	2.904	0.180
CD(P=0.05)	7.090	5.219	5.931	0.367
CD(P=0.01)	9.548	7.029	7.987	0.493

¹ Mean of three replications (1 egg cluster/replication)

² Mean of five replications (3 individuals/replication)

Figures in parentheses are angular values

recorded on Pusa Bindu followed by 92.30 per cent emergence in Arka Nidhi. The minimum record of adult emergence was obtained on AB - 2 (62.50 %) followed by 'Sagalisingia' (66.60%) and 'Kharua Bengena' (71.40 %). Varieties did influence emergence of *H. vigintioctopunctata* adults significantly.

Statistical analyses indicated that there was a highly significant difference ($P = 0.01$) of growth indices recorded on brinjal varieties. The variety accounting for a considerably high growth index was Pusa Bindu (6.17). The lowest index was worked out for Aruna (2.26) followed by KS - 331 (2.43) and 'Kharua Bengena' (2.48). The varieties Pusa Purple Long and Pusa Uttam were also found suitable for the beetle with growth indices of 5.78 and 5.20, respectively.

4.13.2 Effect of varieties on reproductive parameters adult longevity and sex ratio

Data on mating period, oviposition period, fecundity, rate of oviposition, adult longevity and sex ratio of *H. vigintioctopunctata* on different brinjal varieties are presented in Table 45. It is clear from the analysed data that there were highly significant variations ($P = 0.01$) of these parameters recorded on the varieties. Oviposition period was, however, not affected by varietal influence. The adult male and female of the coccinellid copulated as long as 32.30 minutes in JC - 2 variety and managed to mate only for 18.07 minutes in Pusa Kranti. Preoviposition period also showed significant difference ($P = 0.01$) among varieties. The adult females took as long as 13.44 days before deposition of their first batch of eggs in 'Kharua Bengena', where as in Pant Samrat, Pusa Bindu and Pusa Bhairav, they took less than 8.65 days to oviposit. Oviposition period did not show any significant difference among varieties but fecundity

Table 45. Reproductive parameters, adult longevity and sex ratio of *H. vigintioctopunctata* on brinjal varieties

Variety	Mating period (min.)	Pre-oviposition period (days)	Oviposition period (days)	Fecundity (no. of eggs/female)	Reproductive rate (eggs/female/day)	Adult longevity (days)	Sex ratio Male : Female	
							Lab.	Field
Pusa Kranti	18.07±2.15	9.01±0.68	17.79±2.18	132.90±20.97	7.32±1.08	33.27±2.80	1.47±0.04	1.16±0.02
Pusa Purple Long	26.02±3.05	9.67±1.23	27.01±3.38	273.75±33.74	10.40±0.82	65.36±7.13	1.41±0.04	1.03±0.01
Pusa Bindu	29.32±2.40	8.20±0.89	27.77±3.91	328.26±16.17	12.82±0.96	75.37±6.52	1.28±0.03	1.06±0.08
Pusa Uttam	28.30±1.45	11.85±0.90	21.19±1.82	228.90±17.13	10.73±1.37	61.06±4.39	1.36±0.02	1.02±0.03
Pusa Bhairav	31.00±4.00	8.65±0.71	24.16±2.22	174.46±19.38	7.14±0.69	54.13±3.68	1.29±0.02	1.13±0.05
AB-2	28.00±1.30	10.36±1.02	18.70±1.93	114.40±16.49	6.05±0.86	36.45±2.26	2.77±0.17	1.23±0.08
Aruna	26.45±3.00	11.06±1.26	17.65±1.58	119.50±13.32	6.56±0.71	33.40±2.59	2.63±0.09	1.19±0.02
KS-331	20.15±1.35	9.16±0.82	19.53±2.21	115.50±18.43	5.67±0.78	38.42±3.06	2.18±0.07	1.18±0.06
Pant Samrat	27.50±2.45	8.18±0.57	18.00±2.10	150.76±10.61	8.18±0.64	35.51±2.92	1.61±0.04	1.12±0.05
Arka Keshav	29.55±2.10	10.26±1.10	21.69±2.86	248.33±21.89	11.23±0.72	42.68±1.98	1.73±0.06	1.21±0.09
Arka Nidhi	28.30±3.15	10.96±0.96	20.75±1.98	229.86±18.40	10.86±0.83	48.29±2.86	1.46±0.04	1.09±0.05
Muktakeshi	19.20±1.05	9.99±0.91	21.72±1.86	251.26±25.59	11.43±1.10	43.18±2.60	1.62±0.05	1.17±0.07
Neelam Long	21.00±1.40	11.05±1.13	21.34±2.52	180.20±19.45	8.98±0.81	38.87±3.11	1.56±0.08	1.08±0.02
Kharva Bengena	18.40±3.10	13.44±1.32	20.20±2.31	102.30±11.93	5.16±0.97	41.80±3.25	2.33±0.12	1.20±0.06
JC-2	32.30±3.50	9.36±1.09	24.23±1.87	340.10±18.56	14.13±1.45	56.11±4.56	1.32±0.03	1.04±0.03
Sagalisingia	21.00±1.25	12.19±0.95	20.29±2.09	110.30±14.31	5.58±0.70	44.48±3.29	2.58±0.14	1.13±0.05
S.Ed.±	4.08	1.21	NS	29.23	1.50	7.76	0.14	NS
CD(P=0.05)	8.31	2.48	-	59.57	3.07	15.81	0.28	NS
CD(P=0.01)	11.18	3.33	-	80.12	4.13	21.26	0.38	NS

Mean of three replications (each replication contain one pairs of male and female)

was significantly ($P = 0.01$) affected by the varieties. The highest fecundity (340.10 eggs/female) was recorded on JC - 2 followed by Pusa Bindu (328.26 eggs/female). The variety 'Kharua Bengena' accounted for the lowest fecundity (102.3 eggs/female) followed by 'Sagalisingia' (110.30 eggs/female). Similarly, significant varietal effects ($P = 0.01$) on rate of oviposition also existed. Variety JC - 2 with a maximum rate of oviposition of 14.13 eggs/female/day was followed by Pusa Bindu with 12.82 eggs/female/day, whereas 'Kharua Bengena' registered minimum of 5.16 eggs/female/day.

The adult longevity and sex ratio of *H. vigintioctopunctata* on different brinjal varieties were found to be significantly different ($P = 0.01$). The mean duration of adult stage was longest (75.37 days) on Pusa Bindu and shortest (33.27 days) on Pusa Kranti. Varieties, Pusa Purple Long and Pusa Uttam also registered comparatively longer adult longevity (61.06 to 65.36 days), while nine varieties showed comparatively shorter longevity ranging from 33.40 to 48.29 days, which were *at par* ($P = 0.05$). The male to female ratio of *H. vigintioctopunctata* observed in the laboratory differed significantly ($P = 0.01$) among varieties. For every female, 2.77 numbers of male were encountered in variety AB - 2, which was the highest, while 1.28 male /female in Pusa Bindu was the lowest. A higher sex ratio (> 2) was also achieved from Aruna, 'Sagalisingia', 'Kharua Bengena' and KS - 331, whereas lower sex ratios (< 1.40) were found in varieties Pusa Uttam, JC - 2 and Pusa Bhairav. However there were no significant differences among varieties in respect of sex ratios in the field collected population. The sex ratios ranged from 1.02 - 1.23. Highest being recorded on AB - 2 and lowest on Pusa Uttam.

4.13.3 Effect of varieties on leaf area consumption

Varietal effect on feeding behavior of *H. vigintioctopunctata* was studied in the laboratory. The data on leaf area consumption of the grubs and adults of the beetle are presented in Table 46.

The leaf area consumed by larvae in different stages significantly differed ($P = 0.01$) from variety to variety. The first instar larva consumed more leaf tissues while feeding on leaves of Pusa Bindu ($0.70 \text{ cm}^2/48 \text{ h}$). The variety least suitable for feeding of the first instar grub was 'Kharua Bengena' with a consumption of $0.26 \text{ cm}^2/48 \text{ h}$. Leaf consumption by the first instar larvae was comparatively less in Aruna, Pant Samrat, KS - 331 and Muktakeshi in which feeding ranged from 0.28 to 0.31 cm^2 in 48 h. Rest of the varieties were relatively more suitable for larval consumption. Similarly, second, third and fourth instar larvae also exhibited significant variations of feeding on different varieties of brinjal. However, suitability of a particular variety in terms of leaf area consumption remained almost consistent for the grubs in different instars. The mean leaf area consumption/48 h by a grub in its larval life showed that Pusa Bindu was the most preferred variety ($7.68 \text{ cm}^2/48 \text{ h}$) and 'Kharua Bengena' was the least preferred one ($1.99 \text{ cm}^2/48 \text{ h}$) and both were significantly different from other varieties. In varieties, Pusa Purple Long, Pusa Uttam, Pusa Bhairav and JC - 2 the larvae could comfortably consume more than 5 cm^2 in 48 h. Adult beetles also exhibited similar rate of consumption as did the grubs in different varieties. Pusa Bindu was the most favoured food followed by Pusa Purple Long and Pusa Uttam with a leaf area consumption ranging from 13.32 to 20.20

Table 46. Leaf area consumption of *H. vigintioctopunctata* on brinjal varieties

Variety	Leaf area consumption/48 h. (cm ²)					
	Larval stages					Adult
	Instar I	Instar II	Instar III	Instar IV	Mean	
Pusa Kranti	0.36	1.80	3.40	7.50	3.26	8.80
Pusa Purple Long	0.54	3.30	9.28	12.70	6.45	14.60
Pusa Bindu	0.70	3.60	9.80	16.64	7.68	20.20
Pusa Uttam	0.46	3.00	7.90	11.50	5.71	13.32
Pusa Bhairav	0.48	2.70	7.56	11.70	5.61	11.92
AB-2	0.38	1.80	4.60	7.30	3.52	8.50
Aruna	0.31	1.09	3.68	6.46	2.88	8.24
KS-331	0.29	2.20	4.64	7.70	3.70	9.16
Pant Samrat	0.30	2.60	4.50	8.56	3.99	9.40
Arka Keshav	0.52	2.96	5.10	9.20	4.44	10.40
Arka Nidhi	0.46	3.14	5.36	8.66	4.40	11.60
* Muktareshi	0.28	2.16	4.52	7.40	3.59	9.40
Neelam Long	0.48	3.09	5.80	8.90	4.56	10.20
Kharua Bengena	0.26	1.50	2.70	3.52	1.99	5.08
JC-2	0.42	2.86	7.96	9.78	5.25	11.80
Sagalisingia	0.49	1.90	4.18	6.56	3.28	9.40
S.Ed.±	0.024	0.097	0.155	0.189	0.113	0.218
CD(P=0.05)	0.049	0.198	0.317	0.387	0.221	0.446
CD(P=0.01)	0.067	0.266	0.427	0.522	0.291	0.601

Average of three observations

cm²/48 h, while 'Kharua Bengena' was the least favoured one followed by Aruna and AB - 2 (5.08 to 8.5 cm²/48 h).

4.14 Physical characters of brinjal varieties

Data on physical characters of brinjal varieties, viz., foliage density, leaf area, leaf thickness, angle of leaf attachment, pilosity, veinlet density, stomatal density and leaf colour are presented in Table 47, 48 and 49.

4.14.1 Foliage density

Data on foliage density of different brinjal varieties are presented in Table 47. The mean foliage density ranged from 15.00 leaves/plant in Neelam Long to 77.00 leaves/plant in Aruna. The latter was closely followed by Pusa Purple Long (71.33/plant), Pusa Kranti (69.67/plant), 'Sagalisingia' (68.67/plant), 'Kharua Bengena' (62.67/plant), and Pusa Bindu (60.33/plant). Whereas Muktakeshi, Pant Samrat, KS-331, Arka Nidhi and Arka Keshav had significantly lower foliage densities (16.67 – 24.00/plant).

▲ Statistical analysis showed significant difference among the varieties.

4.14.2 Leaf area

It is evident from Table 47 that the area of leaves increased with the increase in age. The maximum area of young leaf was found in Muktakeshi (49.10 cm²) while minimum was recorded on Pusa Kranti (18.43 cm²) followed by Aruna (19.27 cm²) and Pusa Uttam and AB-2 (20.67 cm²). Muktakeshi possessed the biggest (93.97 cm²) medium aged leaves and Aruna the smallest (34.43 cm²). Similarly, in respect of older leaf also, Muktakeshi registered the largest leaf area (187.86 cm²), while Pusa Uttam had

Table 47. Foliage density, leaf area, leaf thickness and angle of leaf attachment of brinjal varieties

Variety	¹ Foliage density (leaves/plant)	¹ Leaf area (cm ²)			² Leaf thickness (mm)	² Angle of leaf attachment (degree)
		Young leaf	Medium aged leaf	Old leaf		
Pusa Kranti	69.67	18.43	60.90	116.83	0.240	76.33
Pusa Purple Long	71.33	25.67	56.77	101.50	0.177	79.67
Pusa Bindu	60.33	29.13	79.30	127.70	0.213	58.33
Pusa Utam	40.67	20.67	37.20	61.37	0.186	41.33
Pusa Btairav	41.67	23.63	49.53	98.37	0.127	60.00
AB-2	55.33	20.67	41.03	79.26	0.293	55.00
Aruna	77.00	19.27	34.43	67.06	0.113	53.33
KS-331	21.33	27.26	72.43	142.00	0.153	38.00
Pant Samrat	17.00	42.20	86.06	166.33	0.163	70.33
* Arka Keshav	24.00	40.47	88.13	150.36	0.206	62.33
Arka Nidhi	21.67	30.10	73.20	133.90	0.217	48.33
Muktakeshi	16.67	49.10	93.97	187.86	0.230	63.33
Neelam Long	15.00	31.07	74.63	150.23	0.130	46.67
Kharua Bengena	62.67	24.00	49.87	100.70	0.203	46.33
JC-2	38.00	41.30	89.77	153.27	0.173	49.67
Sagalisingia	68.67	28.17	70.77	147.60	0.147	88.33
S.E.d.±	9.23	1.58	2.72	5.42	0.024	2.96
CD(P=0.05)	18.82	3.22	5.54	11.05	0.049	6.03
CD(P=0.01)	25.31	4.33	7.45	14.86	0.066	8.11

¹ Mean of three observations

² Mean of six observations

Young, medium and old aged leaves were picked from top, mid and bottom and third of canopy, respectively.

the smallest leaf area (61.37 cm²). Data on leaf area of different age groups of the varieties varied significantly (P = 0.01).

4.14.3 Leaf thickness

Data on leaf thickness tabulated in Table 47, clearly indicated that there were significant variations (P = 0.01) among brinjal varieties. The thickest leaf was found on AB-2 (0.293 mm) and the thinnest on Aruna (0.113 mm), followed by Pusa Bhairav (0.127 mm), Neelam Long (0.130 mm), 'Sagalisingia' (0.147 mm) and KS-331 (0.153 mm), which were *at par*.

4.14.4 Angle of leaf attachment

Data on angle of leaf attachment of different brinjal varieties are presented in Table 47. Significant difference existed among varieties in this regard. The largest angle was recorded on 'Sagalisingia' (88.33 degrees) and the smallest was recorded on KS-331 (38.00 degree), which was *at par* with Pusa Uttam (41.33 degree).

* 4.14.5 Leaf pilosity

The statistical analysis of the data (Table 48) on leaf pilosity (both upper and lower surface of young, medium aged and older leaves) exhibited significant difference among the varieties. The leaf pilosity decreased with the advancement of age of the leaf. The maximum pilosity (188.00 hairs/9 mm² on lower surface) of young leaf was found on variety Aruna. The least pilosity on both the surfaces of young leaf was found on AB-2 (50.00 hairs/9 mm² on lower and 31.00 hairs/9 mm² on upper surface). Varieties KS-331, Muktakeshi and JC-2 also recorded comparatively higher leaf pilosities ranging

Table 48. Leaf pilosity of brinjal varieties

Variety	¹ Pilosity (no. of hairs/cm ²)					
	Young leaf		Medium aged leaf		Old leaf	
	U	L	U	L	U	L
Pusa Kranti	49.00	109.00	36.33	80.33	26.33	60.00
Pusa Purple Long	68.00	98.00	53.33	76.00	42.33	56.33
Pusa Bindu	37.67	59.00	20.67	46.33	14.30	29.66
Pusa Utam	45.67	73.67	27.33	49.00	12.66	38.00
Pusa Bhairav	73.60	110.33	52.00	89.00	31.00	56.00
AB-2	31.00	50.00	23.33	36.00	18.00	29.66
Aruna	126.67	188.00	11.67	160.67	100.66	146.33
KS-331	108.00	130.00	90.00	123.67	68.00	100.33
Pant Samrat	51.33	76.33	37.67	55.33	29.33	37.00
Arka Keshav	64.33	87.67	40.33	57.00	24.00	36.00
Arka Nidhi	76.00	98.00	61.67	78.67	35.00	55.67
Muktakeshi	91.67	121.33	83.33	113.33	70.33	96.33
Neelam Long	64.67	110.00	49.67	84.67	16.33	35.67
Kharua Bengena	57.66	64.00	46.00	52.00	30.67	49.66
JC-2	85.00	120.33	73.00	99.67	64.67	83.66
Sagalisingia	58.00	109.67	40.67	89.00	19.33	64.00
S.Ed±	2.55	3.11	2.13	2.44	2.49	2.38
CD(P=0.05)	5.19	6.35	4.34	4.97	5.07	4.85
CD(P=0.01)	6.98	8.54	5.84	6.68	6.82	6.53

¹ Mean of three replications

U = Upper surface, L = Lower surface

Young, medium and old aged leaves were picked from top, mid and bottom one third of canopy, respectively

from 120.33 - 130.00 hairs/9 mm² on lower surface and 85.00 - 108.00 hairs/ 9 mm² on upper surface.

In case of medium aged leaf, the maximum pilosity on both surfaces was found on Aruna (160.67 hairs/9 mm² on lower surface and 111.67 hairs/9 mm² on upper surface), while minimum was recorded in AB-2 (36.00 hairs/9 mm² on lower surface) and Pusa Bindu (20.67 hairs/9 mm² on upper surface).

In older leaf also, maximum pilosity on both surfaces was found in Aruna (146.33 hairs/9 mm² on lower surface and 100.66 hairs/9 mm² on upper surface) and minimum pilosity was found in Pusa Bindu and AB-2 (29.66 hairs/9 mm² on lower surface) and Pusa Uttam (12.66 hairs/9 mm² on upper surface) followed closely by Neelam Long (35.67 hairs/9 mm² on lower surface and 16.33 hairs/9 mm² on upper surface). However, pilosity in Pusa Bindu and AB-2 on upper surface were 14.30 hairs/9 mm² and 18.00 hairs/9 mm², respectively, whereas pilosity in Pusa Uttam on lower surface was 38.00 hairs/9 mm².

4.14.6 Veinlet density

Data on veinlet density of brinjal varieties are shown in Table 49. The data showed significant difference among the varieties in this regard. Variety 'Sagalisingia' contained the highest number of veinlets (116.33/35 mm²) followed by Muktakeshi (111.66/35 mm²), whereas Pusa Kranti possessed the lowest (49.33/35 mm²), Neelam Long (103.00/35 mm²) and JC-2 (104.00/35 mm²) also recorded higher veinlet densities.

4.14.7 Stomatal density

Data on stomatal density of brinjal varieties are presented in Table 49. Analysis of variance showed significant differences of stomatal densities among varieties. The number of stomata varied from 23.33/40X mic-field in 'Sagalisingia' to 68.33/40X mic-field in KS-331. Variety Arka Keshav (27.33/40X mic-field) also registered lower stomatal density.

4.14.8 Leaf colour

Data on leaf colour of brinjal varieties are presented in Table 49. Statistical analysis showed that there were significant differences among varieties with regards to leaf colour (red, yellow, blue, green) measured in Lovibond scale. The highest red colour component was found in variety Pusa Bindu (5.18 Lovibond scale) and lowest was measured in Pusa Kranti (1.66 Lovibond scale). The intensity of yellow colour after subtracting the dullness value (*i.e.* red colour) was highest on Pusa Kranti (9.04 Lovibond scale) in comparison to others, while Pusa Bindu (3.82 Lovibond scale) scaled the lowest. The yellow colour on all other varieties ranged from 5.13 to 7.50 Lovibond scale. The leaves of varieties Aruna (2.83 Lovibond scale) and Neelam Long (3.06 Lovibond scale) after subtracting dullness value, were found to be lighter blue coloured. Intensity of blue was more, particularly on 'Sagalisingia' (4.50 Lovibond scale), Pusa Kranti (4.36 Lovibond scale) and Pusa Uttam (4.30 Lovibond scale).

Greenness of the leaf was calculated by eliminating all dullness values. Statistically, the data on intensity of green colour significantly differed among varieties. It showed that the variety Pusa Kranti (13.35 Lovibond scale) possessed darker green

coloured leaves as compared to other varieties. Varieties Pusa Bindu (7.65 Lovibond scale) and Aruna (8.03 Lovibond scale) had lighter green coloured leaves. Whereas, all other varieties had green coloured leaves measuring 8.97 - 11.53 Lovibond scale.

4.15 Biochemical characters of leaves of brinjal varieties

4.15.1 Total nitrogen content

Data on total nitrogen content of leaves of brinjal varieties are presented in Table 50. Varieties Aruna (3.81 %), JC-2 (3.63 %), AB-2 (3.62 %) and Pant Samrat (3.15%) contained higher total nitrogen contents. Lower contents of total nitrogen were found in the leaves of Pusa Purple Long (2.14%), Pusa Uttam (2.18%) and Arka Nidhi (2.19%).

4.15.2 Crude protein content

Data on crude protein content of leaves of brinjal varieties are shown in Table 50. The crude protein content ranged from 13.37 per cent in Pusa Purple Long to 23.81 per cent in Aruna. Varieties JC-2 (26.69%) and AB-2 (22.62%) also had higher crude protein contents.

4.15.3 Potassium content

Data on potassium content of leaves of brinjal varieties are presented in Table 50. Variety Pusa Bindu (1.64%) registered the highest potassium content followed by varieties Pant Samrat (1.52%), Arka Nidhi (1.48%) and Pusa Kranti (1.47%). The lower potassium contents of leaves were recorded in varieties, JC-2 (0.89%), Neelam Long (0.96%) and 'Kharua Bengena' (0.97%).

4.15.4 Crude fibre content

Crude fibre contents of leaves of brinjal varieties are presented in Table 50. The highest content of crude fibre was found in 'Sagalisingia' (19.80%) followed by Muktakeshi (18.20%). Lower crude fibre contents were found in Pusa Bhairav (6.24%), Aruna (7.00 %), Pusa Kranti (8.72%) and Arka Nidhi (9.30%).

4.15.5 Moisture content

Data on moisture content of leaves of brinjal varieties are shown in Table 50. The moisture content of leaves varied from 72.40 - 84.49 per cent registered by variety 'Sagalisingia' (lowest) and Pant Samrat (highest).

4.15.6 Tannin content

Table 50 shown data on tannin content of leaves of brinjal varieties. The highest tannin content was recorded on 'Kharua Bengena' (31.81 mg/g) followed by KS-331 (29.53 mg/g) and 'Sagalisingia' (25.67 mg/g). Lower tannin contents were found in Pusa Uttam (7.76 mg/g), Pusa Kranti (8.52 mg/g), Pusa Purple Long (8.74mg/g) and Pusa Bindu (9.21mg/g).

4.15.7 Total phenol content

Data of total phenol content of the leaves of brinjal varieties are shown in Table 50. The highest total phenol content (4.38mg/g) was recorded on 'Kharua Bengena' followed by 3.91mg/g and 3.36mg/g in 'Sagalisingia' and Pant Samrat, respectively. The lowest level of phenol (2.34mg/g) was estimated in the leaves of Pusa Bindu. Pusa Uttam (2.54mg/g) and Pusa Kranti (2.65mg/g) also registered low levels of phenol.

Table 50. Biochemical composition of leaves of brinjal varieties

Variety	Total nitrogen (%)	Crude protein (%)	Potash (%)	Crude fibre (%)	Moisture (%)	Tannin (mg/g)	Total phenol (mg/g)	Total free amino acid (mg/g)	Total carbohydrate (%)
Pusa Kranti	2.20	13.75	1.47	8.72	80.67	8.52	2.65	0.98	11.93
Pusa Purple Long	2.14	13.37	1.31	14.60	82.01	8.74	2.78	1.08	12.18
Pusa Bindu	2.62	16.37	1.64	13.40	81.00	9.21	2.34	1.10	10.60
Pusa Utam	2.18	13.62	1.32	11.80	75.34	7.76	2.54	0.90	10.70
Pusa Bhairav	2.58	16.12	1.30	6.24	80.35	11.85	2.70	1.24	13.50
AB-2	3.62	22.62	1.13	13.60	82.41	12.01	3.25	1.09	13.00
Aruna	3.81	23.81	1.43	7.00	82.82	10.90	3.02	0.95	12.86
KS-331	2.38	14.87	1.40	13.20	82.44	29.53	4.17	1.03	11.58
Pant Samrat	3.15	19.69	1.52	14.60	84.49	14.36	3.36	1.32	13.24
Arka Keshav	2.44	15.25	1.36	12.30	82.40	11.35	2.72	0.86	12.70
Arka Nidhi	2.19	13.68	1.48	9.30	84.32	12.10	2.86	0.93	12.48
Muktakeshi	2.50	15.68	1.08	18.20	73.57	13.80	3.18	1.36	15.25
Neelam Long	2.67	16.68	0.96	17.20	75.75	10.25	2.74	0.91	11.36
Kharua Bengena	2.26	14.12	0.97	17.80	74.66	31.81	4.38	0.94	10.16
JC-2	3.63	22.69	0.89	16.80	75.20	18.08	3.12	1.29	16.56
Sagalisingia	2.35	14.69	1.13	19.80	72.40	25.67	3.91	1.16	13.20

Estimations were done from a composite sample of 15-30 leaves collected from top, middle and bottom canopy of each variety

4.15.8 Total free amino acid

Data on total free amino acid of leaves of brinjal varieties are presented in Table 50. Total free amino acid content ranged from 0.86 mg/g in Arka Keshav to 1.36 mg/g in Muktakeshi. While varieties Pant Samrat, JC-2 and Pusa Bhairav contained higher amino acid content ranging from 1.24 - 1.32 mg/g.

4.15.9 Total carbohydrate content

Data on total carbohydrate content of the varieties are presented in Table 50. Total carbohydrate contents in the varieties ranged from 10.16 per cent in 'Kharua Bengena' to 16.56 per cent in JC-2. Variety Muktakeshi (15.25 %) also contained comparatively higher carbohydrate content.

4.16 Association of physical and biochemical characters of brinjal varieties with infestation and life-parameters of *A. gossypii*

Population density and life parameters such as nymphal period and rate of reproduction of *A. gossypii* showed significant difference among brinjal varieties. Hence, correlations of these parameters with physical and biochemical characters of brinjal varieties were studied.

4.16.1 Correlation of physical characters

4.16.1.1 Leaf area

Correlation studies (Table 51 and 52) revealed that no significant relationship of leaf area existed with population density, nymphal period and rate of reproduction of *A. gossypii*.

Table 51. Association of physical characters of brinjal varieties with population density of *A. gossypii* and *H. vigintioctopunctata*

Physical character	Population density of <i>A. gossypii</i>		Population density of <i>H. vigintioctopunctata</i>	
	Statistical parameters		Statistical parameters	
	r	k	r	k
Leaf Area				
Young leaf	0.343	11.764	(-) 0.046	0.212
Medium aged leaf	0.299	8.940	(-) 0.007	0.004
Older leaf	0.269	7.236	(-) 0.198	3.920
Leaf pilosity				
<i>Young leaf</i>				
Upper surface	(-) 0.104	1.081	(-) 0.286	8.179
Lower surface	(-) 0.007	0.004	(-) 0.255	6.502
<i>Medium aged leaf</i>				
Upper surface	(-) 0.088	0.774	(-) 0.332	11.022
Lower surface	(-) 0.036	0.129	(-) 0.304	9.242
<i>Older leaf</i>				
Upper surface	(-) 0.112	1.254	(-) 0.303	9.181
Lower surface	(-) 0.123	1.513	(-) 0.372	13.838
Foliage density	(-) 0.150	2.250	0.050	0.250
Leaf thickness	0.105	1.102	(-) 0.025	0.062
Angle of leaf attachment	0.264	6.969	(-) 0.037	0.137
Veinlet density	0.429	18.404	(-) 0.059	0.348
Stomatal density	(-) 0.366	13.396	(-) 0.369	13.616
Leaf colour				
Red	(-) 0.044	0.194	0.420	17.640
Yellow	0.422	17.808	0.073	0.533
Blue	0.154	2.372	0.367	13.468
Green	0.408	16.646	(-) 0.198	3.920

All the correlation co-efficients are non significant at P = 0.05

4.16.1.2 Leaf pilosity

Leaf pilosity of brinjal varieties did not show significant correlation with population density, nymphal period and rate of reproduction of A. gossypii. (Table 51 and 52).

4.16.1.3 Foliage density

The correlations of foliage density of brinjal varieties with population density, nymphal period and rate of reproduction of *A. gossypii* were non-significant (Table 51 and 52).

4.16.1.4 Leaf thickness

Correlation studies (Table 51 and 52) indicated that no significant correlations of leaf thickness existed with population density, nymphal period and rate of reproduction of *A. gossypii*.

4.16.1.5 Angle of leaf attachment

Correlation studies (Table 51 and 52) showed that there was no significant relationship between angle of leaf attachment with the population density, nymphal period and rate of reproduction of *A. gossypii*.

4.16.1.6 Veinlet density

Veinlet density of brinjal leaf did not show any significant correlation with population density, nymphal period and rate of reproduction of *A. gossypii* (Table 51 and 52).

Table 52. Association of physical characters of brinjal varieties with life parameters of *A. gossypii*

Physical character	Nymphal period		Rate of reproduction by adult female	
	Statistical parameters		Statistical parameters	
	r	k	r	k
Leaf Area				
Young leaf	(-) 0.088	0.774	0.227	5.153
Medium aged leaf	(-) 0.114	1.299	0.276	7.618
Older leaf	(-) 0.074	0.547	0.236	5.569
Leaf pilosity				
<i>Young leaf</i>				
Upper surface	0.293	8.585	(-) 0.210	4.410
Lower surface	0.109	1.188	(-) 0.128	1.638
<i>Medium aged leaf</i>				
Upper surface	0.299	8.940	(-) 0.218	4.752
Lower surface	0.161	2.592	(-) 0.138	1.904
<i>Older leaf</i>				
Upper surface	0.313	9.797	(-) 0.242	5.856
Lower surface	0.273	7.453	(-) 0.252	6.350
Foliage density	0.024	0.057	(-) 0.170	2.890
Leaf thickness	(-) 0.087	3.497	0.093	0.865
Angle of leaf attachment	(-) 0.296	8.762	0.272	7.398
Veinlet density	(-) 0.352	12.390	0.390	15.210
Stomatal density	0.391	15.288	(-) 0.241	5.808
Leaf colour				
Red	0.009	0.008	0.071	0.504
Yellow	(-) 0.464	21.529	0.278	7.728
Blue	(-) 0.236	5.569	0.257	6.605
Green	(-) 0.437	19.097	0.271	7.344

All the correlation co-efficients are non significant at P = 0.05

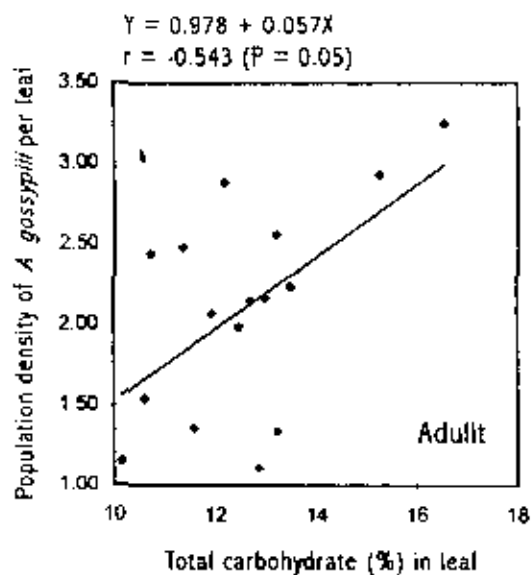
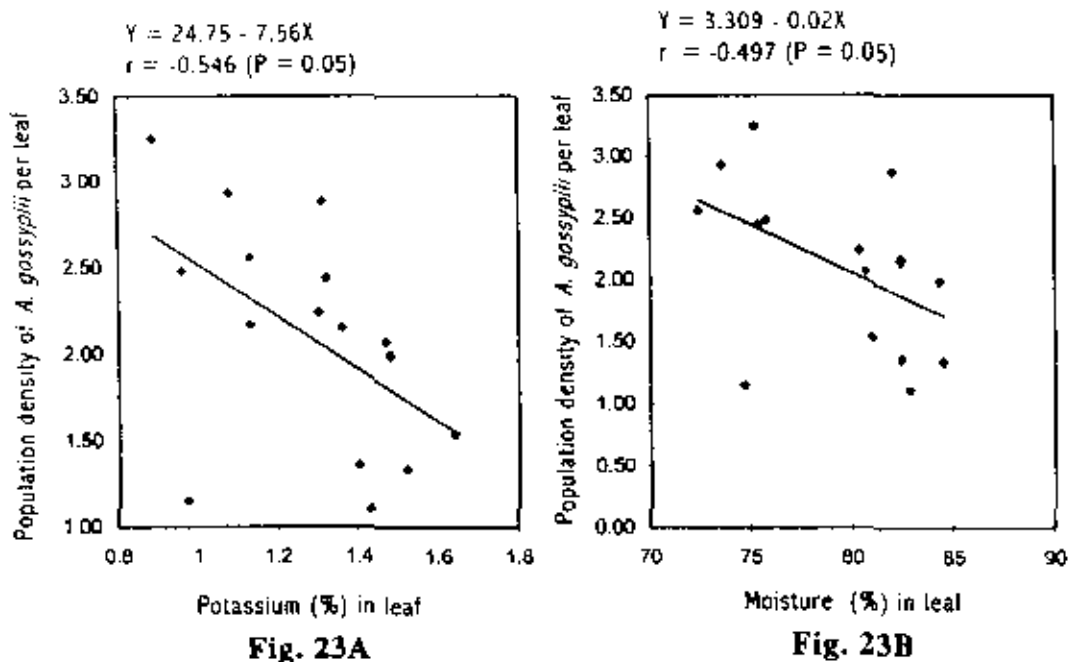


Fig. 23. Relationship of population density of *A. gossypii* with (A) potassium, (B) moisture and (C) total carbohydrate contents of brinjal leaf

4.16.1.7 Stomatal density

Non-significant correlation existed between stomatal density of brinjal leaf with population density, nymphal period and rate of reproduction of *A. gossypii*. (Table 51 and 52).

4.16.1.8 Leaf colour

Leaf colour did not have any effect on population density, nymphal period and rate of reproduction of *A. gossypii*. Correlation coefficients were presented in Table 51 and 52.

4.16.2 Correlation with biochemical characters

4.16.2.1 Total nitrogen content

Table 53 showed that no significant relationship of total nitrogen content of leaf existed with the population density, nymphal period and rate of reproduction of *A. gossypii*.

4.16.2.2 Crude protein content

Crude protein content of the brinjal leaf did not significantly influence the population density, nymphal period and rate of reproduction of *A. gossypii* (Table 53).

4.16.2.3 Potassium content

Potassium content of leaves of brinjal varieties was found to have significant negative correlations with population density ($r = -0.546$, $P = 0.05$) of *A. gossypii* (Table 53). However, no relationship existed between potassium content with nymphal period and rate of reproduction of the aphid.

Table 53. Association of biochemical characters of brinjal varieties with population density and life parameters of *A. gossypii*

Biochemical constituents	Statistical parameters			Population density	Nymphal period			Rate of nymphal deposition
	r	k	Y		r	k	Y	
Total nitrogen	r	-0.073			0.086		0.047	
	k	0.533			0.739		0.221	
	Y	-			-		-	
Crude protein	r	-0.136			0.052		-0.036	
	k	1.849			0.270		0.129	
	Y	-			-		-	
Potash	r	-0.546*			0.276		-0.417	
	k	29.812			7.617		17.388	
	Y	24.75-7.56X			-		-	
Crude fibre	r	0.744			-0.136		0.248	
	k	11.834			1.849		6.150	
	Y	-			-		-	
Moisture content	r	-0.497*			0.323		-0.195	
	k	24.701			10.433		3.802	
	Y	3.309-0.02X			-		-	
Tannin	r	-0.270			0.411		-0.206	
	k	7.290			16.892		4.244	
	Y	-			-		-	
Total phenol	r	-0.315			0.454		-0.251	
	k	9.922			20.612		6.300	
	Y	-			-		-	
Total free amino acid	r	0.323			-0.205		0.365	
	k	10.433			4.202		13.323	
	Y	-			-		-	
Total carbohydrate	r	0.543*			-0.407		0.483	
	k	29.485			16.565		23.329	
	Y	0.978+0.057X			-		-	

*Significant at P = 0.05

The regression equation $Y = 24.75 - 7.56X$ expressed the extent of relationship of 'K' content of leaf with population density of *A. gossypii* (Figure 23A).

4.16.2.4 Crude fibre content

No significant relationship of crude fibre content of brinjal leaves existed with the population density, nymphal period and rate of reproduction of *A. gossypii* (Table 53).

4.16.2.5 Moisture content

Moisture content did not have any significant correlation with the nymphal period and rate of reproduction of *A. gossypii*. Population density, however, had significant *negative relationship with the moisture content* ($r = - 0.497, P = 0.05$) (Table 53).

The regression equation expressing the relationship of leaf moisture content with population density of *A. gossypii* was $Y = 3.309 - 0.202X$ (Figure 23B)

4.16.2.6 Tannin content

Tannin content of brinjal leaves did not have any significant influence on population density, nymphal period and rate of reproduction of *A. gossypii* (Table 53).

4.16.2.7 Total phenol content

Population density, nymphal period and rate of reproduction of *A. gossypii* were not significantly affected by total phenol content of brinjal leaves (Table 53).

4.16.2.8 Total free amino acid content

A. gossypii infestation and the life parameters had no significant correlation with the total free amino acid content of brinjal leaves (Table 53).

4.16.2.9 Total carbohydrate content

No significant correlation of total carbohydrate content of brinjal varieties existed with nymphal period and rate of reproduction of *A. gossypii*. However, positive significant correlation ($r = 0.543$, $P = 0.05$) resulted with total carbohydrate and population density (Table 53). The association was expressed by the equation $Y = 0.978 + 0.057X$ (Figure 23C).

4.17 Association of physical and biochemical characters of brinjal varieties with infestation and life parameters of *H. vigintioctopunctata*

Population density, larval period, pupal period, adult longevity, fecundity, rate of oviposition and sex ratio of *H. vigintioctopunctata* were found to be significantly influenced by the brinjal varieties. Thus correlation of these parameters with different physical and biochemical characters of the brinjal varieties were studied.

4.17.1 Correlation of physical characters

4.17.1.1 Leaf area

Table 51 and 54 showed that there were no significant correlation between leaf area of brinjal varieties with the population density, larval period, pupal period, adult longevity, fecundity and sex ratio of *H. vigintioctopunctata*. However, significant positive correlation existed between leaf area of young leaf with rate of oviposition ($r = 0.551$, $P = 0.05$) and medium aged leaf with rate of oviposition ($r = 0.532$, $P = 0.05$). Regression equations $Y = 3.937 + 0.168X$ and $Y = 3.803 + 0.076X$, respectively

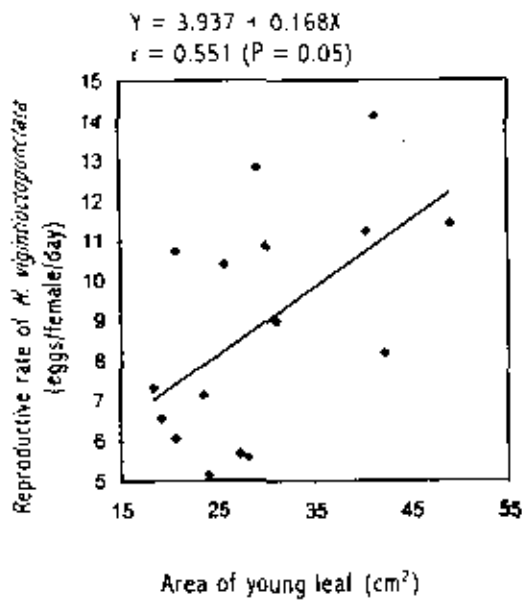


Fig. 24A

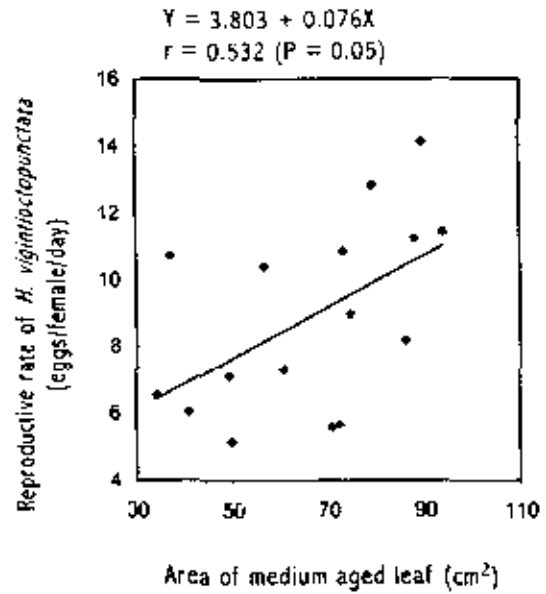


Fig. 24B

Fig. 24. Relationship of reproductive rate of *H. vigintioctopunctata* with (A) young leaf area and (B) medium aged leaf area of brinjal

Table S4. Association of leaf area and leaf pilosity of brinjal varieties with life parameters of *H. vigintioctopunctata*

Plant physical characters	Statistical parameters	Larval period	Pupal period	Adult longevity	Fecundity	Rate of oviposition	Sex ratio
Leaf Area	r	0.092	-0.009	0.009	0.481	0.551*	-0.312
	k	0.846	0.008	0.008	23.136	30.360	9.734
	Y	-	-	-	-	3.937+0.168X	-
Medium leaf	r	-0.034	-0.074	0.052	0.481	0.532*	-0.389
	k	0.115	0.547	0.270	23.136	28.302	15.132
	Y	-	-	-	-	3.803+0.076X	-
Old leaf	r	0.126	-0.094	-0.132	0.266	0.324	-0.254
	k	1.587	0.883	1.742	7.075	10.497	8.452
	Y	-	-	-	-	-	-
Leaf pilosity	r	0.183	-0.186	-0.263	0.063	-0.057	0.164
	k	3.348	3.459	6.916	0.396	0.325	2.689
	Y	-	-	-	-	-	-
Young leaf	r	0.165	-0.329	-0.328	1.137	-0.111	0.152
	k	2.723	10.824	10.758	1.876	1.232	2.310
	Y	-	-	-	-	-	-
Upper surface	r	0.231	-0.106	-0.308	0.080	-0.066	0.206
	k	5.336	1.124	9.486	0.640	0.435	4.243
	Y	-	-	-	-	-	-
Lower surface	r	0.168	-0.240	-0.312	0.148	-0.139	0.200
	k	2.822	5.760	9.734	2.190	1.932	4.000
	Y	-	-	-	-	-	-
Medium aged leaf	r	0.234	-0.012	-0.257	0.017	-0.011	0.226
	k	5.476	0.014	6.604	0.029	0.012	5.107
	Y	-	-	-	-	-	-
Upper surface	r	0.262	-0.158	-0.302	0.165	-0.158	0.319
	k	6.864	2.496	9.120	2.723	2.496	18.176
	Y	-	-	-	-	-	-
Lower surface	r	0.262	-0.158	-0.302	0.165	-0.158	0.319
	k	6.864	2.496	9.120	2.723	2.496	18.176
	Y	-	-	-	-	-	-

* Significant at P = 0.05

expressed the magnitude of these associations (Figure 24A and 24B). While older leaves did not have any relationship.

4.17.1.2 Leaf pilosity

Pilosity of brinjal leaves had no significant relationship with any of the parameters of *H. vigintioctopunctata* studied (Table 51 and 54).

4.17.1.3 Foliage density

Table 51 and 55 shows that none of the infestation and life parameters of *H. vigintioctopunctata* studied were significantly correlated with the foliage density of brinjal varieties.

4.17.1.4 Leaf thickness

Leaf thickness had no significant influence on population density, larval period, pupal period, adult longevity, fecundity, rate of oviposition and sex-ratio of *H. vigintioctopunctata* (Table 51 and 55).

4.17.1.5 Angle of leaf attachment

Angle of leaf attachment of brinjal could not significantly affect the infestation and life parameters of *H. vigintioctopunctata* studied (Table 51 and 55).

4.17.1.6 Veinlet density

Correlation studies (Table 51 and 55) indicated that there were non-significant relationships between veinlet density with population density and life parameters of *H. vigintioctopunctata*.

Table 55. Association of foliage density, leaf thickness, angle of leaf attachment, veinlet density, stomatal density and leaf colours of brinjal varieties with life parameters of *H. viaticopunctata*

Plant physical characters	Statistical parameters	Larval period	Pupal period	Adult longevity	Fecundity	Rate of oviposition	Sex ratio
Foliage density	r	-0.131	0.073	0.160	-0.201	-0.314	0.354
	k	1.716	0.533	2.560	4.040	9.859	12.532
	Y	-	-	-	-	-	-
Leaf thickness	r	0.165	0.417	-0.001	0.118	0.157	0.039
	k	2.722	17.388	0.000	1.392	2.463	0.152
	Y	-	-	-	-	-	-
Angle of leaf attachment	r	0.063	0.057	0.004	-0.040	-0.084	0.011
	k	0.397	0.325	0.002	0.160	0.706	0.012
	Y	-	-	-	-	-	-
Veinlet density	r	-0.093	-0.103	-0.018	0.156	0.163	0.279
	k	0.864	1.061	0.032	2.434	2.657	7.784
	Y	-	-	-	-	-	-
Stomatal density	r	0.338	0.395	-0.385	-0.363	-0.320	0.260
	k	11.424	19.602	14.822	13.176	10.240	6.760
	Y	-	-	-	-	-	-
Leaf colours Red	r	-0.565*	-0.008	0.640**	0.536*	0.511*	-0.221
	k	31.922	0.006	40.960	30.914	26.112	4.884
	Y	22.637-1.361X	-	22.406+9.869X	58.312+54.873X	4.461+1.794X	-
Yellow	r	0.155	0.275	0.055	0.170	0.231	-0.178
	k	1.822	7.562	0.302	2.890	4.410	3.168
	Y	-	-	-	-	-	-
Blue	r	-0.439	0.007	0.588*	0.478	0.439	-0.213
	k	19.272	0.005	34.574	22.848	19.272	4.537
	Y	-	-	0.918+7.351x	-	-	-
Green	r	0.431	0.185	-0.306	-0.209	-0.151	0.026
	k	18.576	3.422	9.363	4.368	2.280	0.067
	Y	-	-	-	-	-	-

* Significant at P = 0.05; ** Significant at P = 0.01

4.17.1.7 Stomatal density

Result of correlation studies shown that stomatal density of brinjal leaf had no significant relationship with infestation and life parameters of *H. vigintioctopunctata* (Table 51 and 55).

4.17.1.8 Leaf colour

Correlation studies (Table 51 and 55) showed that larval period ($r = -0.565$, $P = 0.05$), fecundity ($r = 0.556$, $P = 0.05$) and rate of oviposition ($r = 0.511$, $P = 0.05$) were significantly affected by intensity of red colour of brinjal leaves. Whereas, adult longevity was affected by both red ($r = 0.640$, $P = 0.01$) and blue ($r = 0.588$, $P = 0.05$) colours of brinjal leaves. However, red, yellow, blue and green colour of leaves did not affect the population density and remaining life parameters of *H. vigintioctopunctata* studied.

The regression equations showing the magnitude of relationships of red colour with larval period was $Y = 22.637 - 1.361X$ (Figure 25A), with adult longevity was $Y = 22.406 + 9.869X$ (Figure 25B), with fecundity was $Y = 58.312 + 54.873X$ (Figure 25C) and with rate of oviposition was $Y = 4.461 + 1.794X$ (Figure 25D). While the regression showing the relationship between the intensity of blue colour and adult longevity was $Y = 0.918 + 7.351X$.

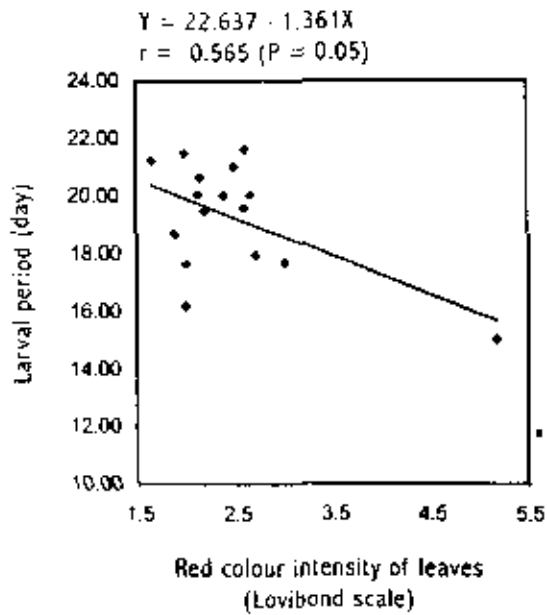


Fig. 25A

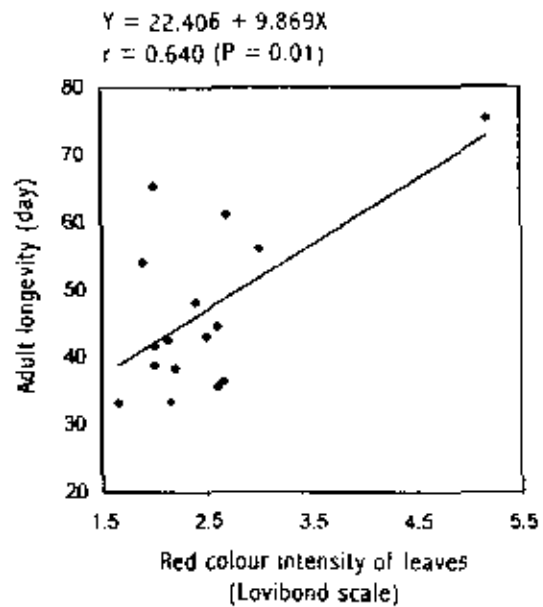


Fig. 25B

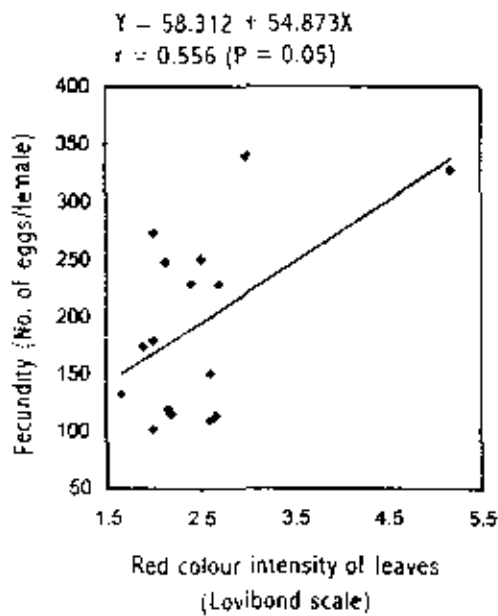


Fig. 25C

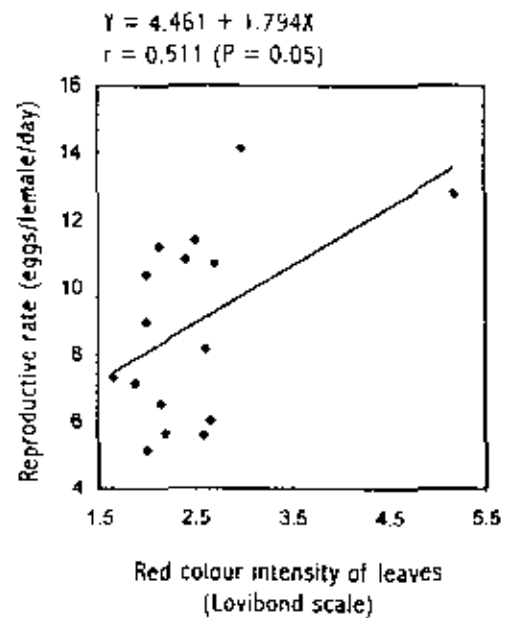


Fig. 25D

Fig. 25. Relationship of red colour intensity of brinjal leaf with (A) larval period, (B) adult longevity, (C) fecundity and (D) reproductive rate of *H. vigintioctopunctata*

4.17.2 Correlation of biochemical characters

4.17.2.1 Total nitrogen content

No significant correlation (Table 56) of total nitrogen contents of brinjal varieties existed with population density and life parameters of *H. vigintioctopunctata* studied.

4.17.2.2 Crude protein content

Correlation studies revealed that crude protein content of brinjal leaves did not have any significant relationship with population density and life parameters of *H. vigintioctopunctata* studied (Table 56).

4.17.2.3 Potassium content

Correlation studies indicated that potassium contents of brinjal leaves were not significantly correlated with infestation and life parameters of *H. vigintioctopunctata* studied (Table 56).

4.17.2.4 Crude fibre content

No significant influence of leaf fibre existed upon infestation and life parameters of *H. vigintioctopunctata* recorded on different brinjal varieties (Table 56).

4.17.2.5 Moisture content

Moisture content of brinjal leaves did not have any significant effect on population density, larval period, pupal period, adult longevity, fecundity, rate of oviposition and sex-ratio of *H. vigintioctopunctata* (Table 56).

Table 56. Association of biochemical characters of brinjal varieties with population density and life parameters of *H. vigintioctopunctata*

Biochemical constituents	Statistical parameters	Population density	Larval period	Pupal period	Adult longevity	Fecundity	Rate of oviposition	Sex ratio
Total nitrogen	r	0.028	-0.107	-0.124	0.010	0.101	0.092	0.335
	k	0.078	1.145	1.537	0.010	1.020	0.846	11.222
	Y	-	-	-	-	-	-	-
Crude protein	r	-0.108	0.101	-0.211	-0.268	-0.043	-0.002	0.360
	k	1.166	1.020	4.452	7.182	0.184	0.000	12.960
	Y	-	-	-	-	-	-	-
Potash	r	0.244	-0.239	0.062	0.321	0.211	0.165	-0.286
	k	5.953	5.712	0.384	10.304	4.452	2.722	8.179
	Y	-	-	-	-	-	-	-
Crude fibre	r	-0.117	-0.066	0.186	0.038	0.100	0.092	0.165
	k	1.369	0.436	3.459	0.144	1.000	0.846	2.722
	Y	-	-	-	-	-	-	-
Moisture content	r	0.005	0.065	0.030	-0.115	-0.062	-0.060	-0.029
	k	0.002	0.422	0.090	1.322	0.384	0.360	0.084
	Y	-	-	-	-	-	-	-
Tannin	r	-0.550*	0.329	-0.105	-0.267	-0.436	-0.498*	0.503*
	k	30.250	10.824	1.102	7.128	19.009	24.800	25.301
	Y	2.324-0.029X	-	-	-	-	11.580-0.182X	1.276+0.034X
Total phenol	r	-0.691**	0.494	-0.034	-0.449	-0.592*	-0.621**	0.654**
	k	47.748	24.404	0.115	20.160	35.046	38.364	42.772
	Y	3.356-0.470X	-	-	-	440.361-79.35X	18.103-2.965X	-0.017+0.581X
Total free amino acid	r	0.030	0.023	0.277	0.112	0.206	0.165	-0.157
	k	0.090	0.053	7.672	1.254	4.243	2.722	2.464
	Y	-	-	-	-	-	-	-
Total carbohydrate	r	-0.004	0.157	0.035	-0.115	0.293	0.329	-0.075
	k	0.002	2.465	-1.225	1.322	8.584	10.824	0.562
	Y	-	-	-	-	-	-	-

* Significant at P = 0.05; ** Significant at P = 0.01

4.17.2.6 Tannin content

Correlation studies (Table 56) indicated that tannin content of brinjal leaves had marked influence on population density ($r = -0.550$, $P = 0.05$), rate of oviposition ($r = -0.498$, $P = 0.05$) and sex ratio ($r = 0.503$, $P = 0.05$) of *H. vigintioctopunctata*. However, it had no significant effect on larval period, pupal period, adult longevity and fecundity of the coccinellid.

The regression equations expressing the relationships of leaf tannin with population density, rate of oviposition and sex ratio of *H. vigintioctopunctata* were $Y = 2.324 - 0.029X$, $Y = 11.580 - 0.182X$ and $Y = 1.276 + 0.034X$, respectively (Figure 26A, 26B and 26C).

4.17.2.7 Total phenol content

Population density ($r = -0.691$, $P = 0.01$), fecundity ($r = -0.592$, $P = 0.05$), rate of oviposition ($r = -0.621$, $P = 0.01$) and sex ratio ($r = 0.654$, $p = 0.01$) were found to possess significant correlations with phenol contents of brinjal varieties (Table 56).

Larval period, pupal period and adult longevity, however, did not have any significant correlation with the phenol content. The regression equation expressing the relationships of leaf phenol with population density, fecundity, rate of oviposition and sex ratio of *H. vigintioctopunctata* were $Y = 3.356 - 0.470X$, $Y = 440.361 - 79.35X$, $Y = 18.103 - 2.965X$ and $Y = -0.017 + 0.581X$, respectively (Figure 27A, 27B, 27C and 27D).

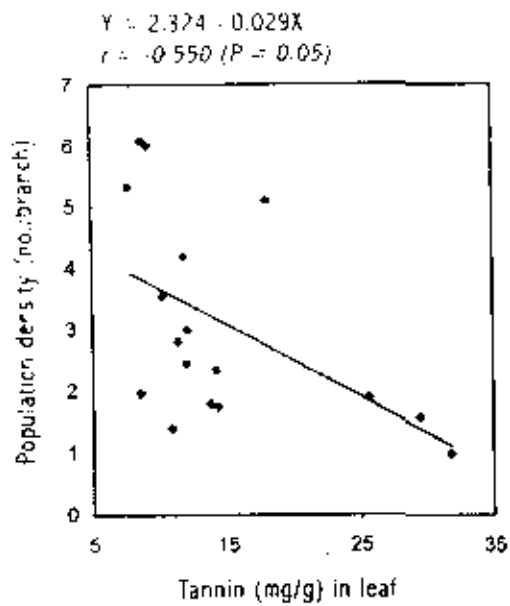


Fig. 26A

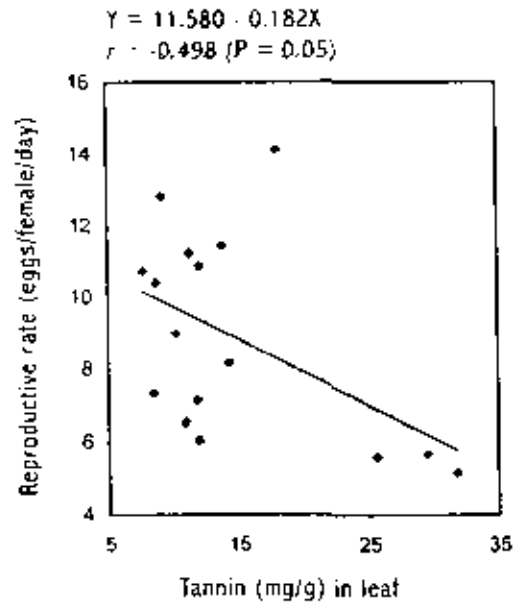


Fig. 26B

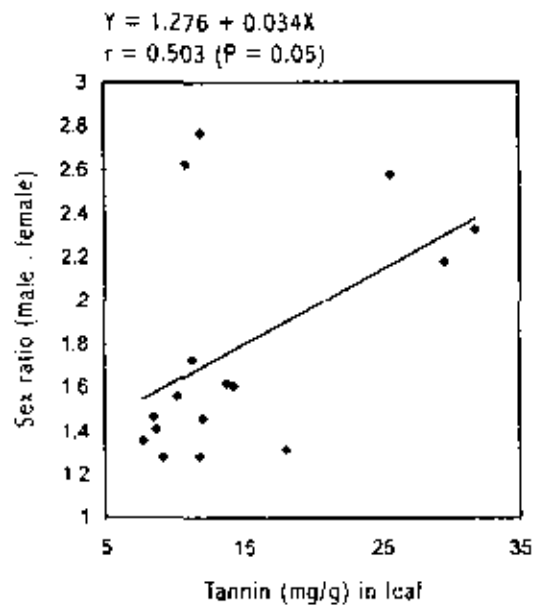


Fig. 26C

Fig. 26. Relationship of tannin content of brinjal leaf with (A) population density, (B) reproductive rate and (C) sex ratio of *H. vigintioctopunctata*

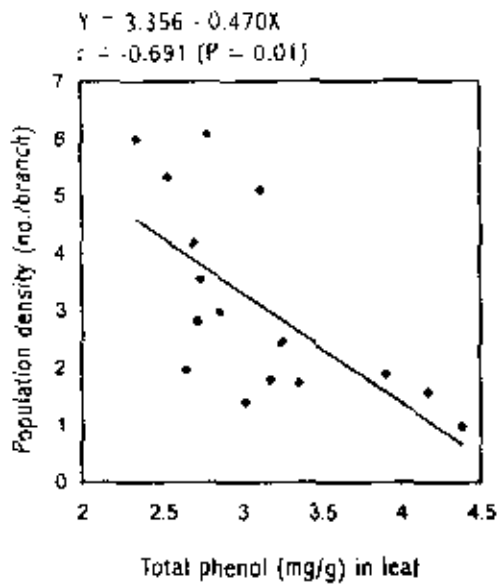


Fig. 27A

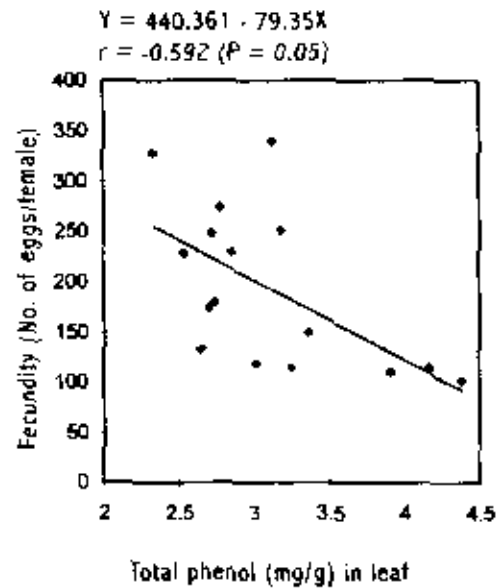


Fig. 27B

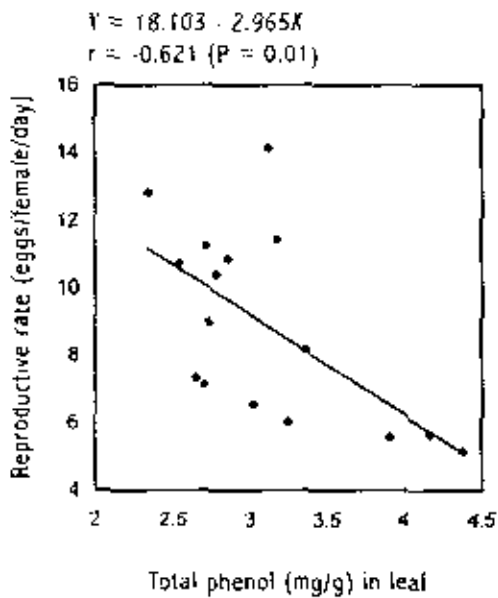


Fig. 27C

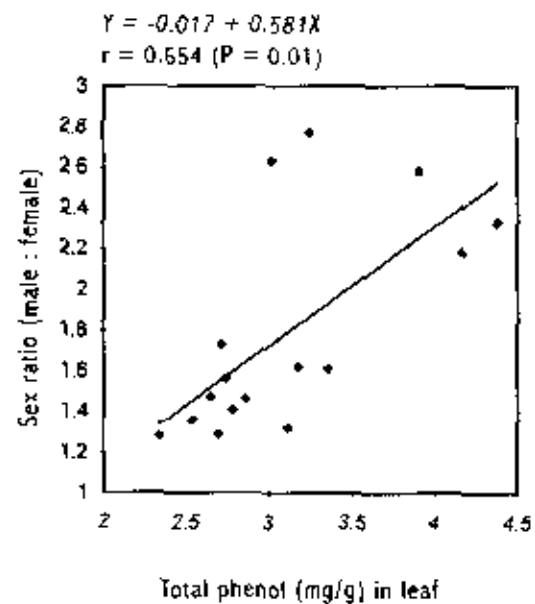


Fig. 27D

Fig. 27. Relationship of total phenol content of brinjal leaf with (A) population density, (B) fecundity, (C) reproductive rate and (D) sex ratio of *H. vigintioctopunctata*

4.17.2.8 Total free amino acid content

Table 56 shows that the association of free amino acid content of brinjal leaves with infestation and life parameters of *H. vigintioctopunctata* studied were non-significant.

4.17.2.9 Total carbohydrate content

Correlation studies revealed that carbohydrate content of brinjal leaves did not have any significant relationship with infestation and life parameters of *H. vigintioctopunctata* (Table 56).

CHAPTER V

DISCUSSION

Brinjal aphid, *Aphis gossypii* Glover is an important sucking pest of brinjal crop throughout the tropics and sub-tropics. In Assam, it has become a major pest of brinjal in recent times. Extremely scanty and sporadic information on this aphid's biology, ecology and varietal screening studies done in other parts of the country are available (Butani and Verma, 1976; Roy and Behura, 1983; Banerjee and Raychaudhuri, 1985; Reddy and Biradar, 1990; Singh *et al.*, 1990). No information on its seasonal incidence, population dynamics, distribution pattern and host plant resistance is available from the north-east region of India, barring a few preliminary studies on ecology and management of this pest made by Kalita (1996).

The 28-spotted epilachna beetle, *Henosepilachna vigintioctopunctata* (Fab.) is a well known major pest of brinjal and is widely distributed in almost all regions of the world. It is a common pest of solanaceous, cucurbitaceous and leguminous crops. This species is recognized as another important pest of brinjal in Assam. Despite few works on its biology, morphology, chemical control and host plant resistance studies in Assam (Sonowal, 1970; Phukan, 1976; Borah, 1977 and Devi, 1988), and some works on its

ecology and varietal screening studies (Suman *et al.*, 1987; Ramzan *et al.*, 1990; and Rajendran and Gopalan, 1998) in other parts of India, information on spatial distribution pattern and various other aspects of this insect is practically scanty.

The present investigation was aimed at understanding the population ecology of these two pests in brinjal crop and to evaluate brinjal varieties for resistance against them.

The results of the present investigation are discussed hereunder.

5.1 Seasonal population trend of *A. gossypii* on brinjal

The attack of *A. gossypii* commenced at the seedling stage of the crop during second week of October (14 October) in 1998 – 1999 and during second week of November (11 November) in 1999 – 2000. The apterous population gradually increased in the field till the crop was approaching early vegetative stage in between second and third week of November for 1998 – 1999 crop, and in between first and second week of December for 1999 – 2000 crop. Whereas, alate adults declined during this period, then increased again in the month of December for 1998 – 99 crop and in the month of January for 1999 – 2000 crop, and finally disappeared from the field in the month of February at the fruit initiation stage. However, apterous nymphs and adults steadily rose from the late vegetative stage of the crop, in the last week of December for the first year crop and in the third week of January for the second year crop. At the time, when alate adults were not present in the field, apterous population reached their peak at the flowering stage of the crop during last week of January for 1998 – 99 crop and last week of February for 1999 – 2000 crop. Then onwards, apterous population declined to its minimum population density and alate adults reappeared and reached its peak during the

month of April, when the crop was at its last stage. Banerjee and Raychaudhuri (1985) recorded the appearance of *A. gossypii* alates on brinjal in West Bengal from late November to late December and peak of aphids (apterous) was recorded in late February, when the plants became matured. Banerjee *et al.* (1986) also found that *A. gossypii* population first appeared in October and peaked in February, when the plants were 5 to 8 months old. They also recorded that per cent alate viviparous female population declined from October till December, then increased again and reached a peak in April. The percentage of apterae increased from November to January. Ghetiya and Butani (1995) also made similar observations on peak of this pest on coriander. While, Araujo and Sales (1985) stated that increase in population of *A. gossypii* on cotton was favoured by the presence of flower bud, which nearly confirmed the present investigation.

Initial aphid populations as recorded on 14 October in 1998 – 99 and 11 November in 1999 – 2000 were 6.93 nymphs/plant, 3.67 apterous adults/plant and 0.40 alate adults/plant; and 2.73 nymphs, 1.20 apterous adults and 0.60 alate adults per plant, respectively. Thereafter, the apterous population decreased and again increased gradually to attain its peak level of 38.00 nymphs and 18.93 adults per 6 leaves on 28 January, and 11.08 nymphs and 3.40 adults per 6 leaves on 24 February during 1998 – 99 and 1999 – 2000, respectively. While alate adults reached their peak of 1.86/6 leaves on 1 April and 1.76/6 leaves on 7 April during first and second year, respectively. The peak nymphal and adult population of apterous form in the present investigation almost coincided (in between R₂ and R₄ stage of the crop) with flowering stage of the crop in both the years. The low aphid population in the second cropping season might be due to the interspecific

competition between *A. gossypii* and the red spider mite, *Tetranychus neocaledonicus* Andre. Infestation of this red spider mite remained in the field from the month of October till the end of February with an approximate population of 30 – 40/cm² leaf. Veeravel and Baskaran (1994) reported similar findings between *A. gossypii* and *H. vigintioctopunctata*, where this aphids were able to eliminate the coccinellids from the plant when aphid population was above 60/plant. However, in the present study no such competitive displacement was seen probably because the experiment was carried out in open field, while the study of Veeravel and Baskaran (1994) was conducted in confinement of a net house, where the environment, plant density and plant nutritional status were different from the present study. Moreover, the crop stage at which the plants were attacked might also be a determining factor. Brinjal plants at mid reproductive stage also had all the reproductive parts such as flower buds, flowers and developing fruits as well as full vegetation with leaves of all ages, which supported maximum population of the aphid. So far as peak period of infestation and crop stages are concerned, the results of the present investigation are in agreement with those of Banerjee and Raychaudhuri (1985), Araujo and Sales (1985) and Banerjee *et al.* (1986).

5.1.1 Impact of natural enemies on *A. gossypii* population

Three coccinellid predators of *A. gossypii* were recorded *viz.*, *Coccinella repanda* Thunb, *Menochilus sexmaculatus* F. and *Micraspis discolor* (F.) (Coccinellidae: Coleoptera). However, no parasitoid could be noticed in the course of the present investigation. All these three predators were earlier recorded from India (Venugopal *et al.*, 1977; Saharia, 1985; Barman, 1992), from Bangladesh (Haque and Islam, 1982) and

from Japan (Sugiura and Takada, 1998). The population of *C. repanda* increased with the increase in prey population and their peak population reached within zero to three weeks of attainment of peak by *A. gossypii* population. An adult *C. repanda* could consume 26.33 – 29.90 aphids/day. This coccinellid predator showed significant positive association with the population of apterous morphs of the prey. Similar type of association was also recorded by Venugopal *et al.* (1977) on Okra.

M. sexmaculatus, a predatory coccinellid was found preying on *A. gossypii* nymphs and adults. The population of this predator increased gradually with the prey population and attained their peak either perfectly coinciding or one week before aphid population peak. The population of this predator showed significant positive correlation with the apterous prey population in both the years. This predator could consume 15.88 – 16.55 aphids/day. Similar predator – prey association were also reported by Venugopal *et al.* (1977) and, Srikanth and Lakkhundi (1990). Palaniswami and Pillai (1981) recorded that a single *M. sexmaculatus* could consume 15 – 18 aphids/day, which almost corroborated the results of the present investigation.

M. discolor, an another coccinellid predator, was also found preying upon *A. gossypii*. They appeared in the field for a shorter period of time and attained their peak when apterous aphid population was at declining trend and alate adults were approaching peak during the later part of crop growth. This predator had a capacity to consume 11.22 – 12.72 aphids/day. It showed significant positive association with the apteroid adult population of *A. gossypii*. Palaniswami and Pillai (1981) recorded similar results. They

found that the mean aphid consumption per day by a *M. discolor* ranged from 10-18 numbers.

5.1.2 Impact of meteorological factors on *A. gossypii* population

* Maximum and minimum temperature showed non-significant negative effect on aphid population. It was evident that the aphids showed a little fall in population in the month of December for the first cropping season and in the month of January for the second cropping season, when the temperature was rather low; and again population decline was evident from February – March, when the temperature was marginally higher. The present findings supported the earlier observations of Araujo and Sales (1985), Banerjee *et al.* (1986), Chattopadhyay *et al.* (1996) and Debaraj *et al.* (1996). Nozato and Abe (1988) found that survival of *A. gossypii* was low on cucumber due to high temperature during warmer season in Japan, while in winter, most of these aphids disappeared due to low temperature in the field.

Morning relative humidity had non-significant positive and evening relative humidity had non-significant negative association with the aphid population during both the years. According to Araujo and Sales (1985), the population of *A. gossypii* was not affected by relative humidity. Banerjee *et al.* (1986) also found a negative relationship between aphid population and relative humidity. However, a positive association between relative humidity and population of *A. gossypii* was reported by Chattopadhyay *et al.* (1996).

Total rainfall and number of rainy days exhibited non-significant negative correlations with aphid population during both the cropping seasons. This finding was

almost in accordance with the works of Araujo and Sales (1985). Roy (1975) also reported non-significant negative correlation between population of *Lipaphis erysimi* (Kalt.) and rainfall. Chattopadhyay *et al.* (1996) and Debaraj *et al.* (1996), however, reported that the numerical abundance of aphid was greatly influenced by rainfall.

Bright sunshine hours exhibited significant positive correlation with nymphal and overall aphid population (nymph + adult) and non-significant positive correlation with adult population in pooled correlation studies, for both the years. Araujo and Sales (1985) observed that the increase of *A. gossypii* population was favoured by bright sunshine hours. Chattopadhyay *et al.* (1996), however, stated that the aphid population increase was closely related with decrease in sunshine hours. Singh *et al.* (1986) also found significant positive correlation between population of *L. erysimi* and sunshine hours.

5.2 Seasonal population trend of *H. vigintioctopunctata* on brinjal

Infestation of *H. vigintioctopunctata* on brinjal occurred in the second week of October in 1998-99 and fourth week of November in 1999-2000, at the seedling stage of the crop. Their gradual decline in population from the month of December at the mid vegetative stage (V₂) followed by gradual increase in population was observed from the third or fourth week of January, in the flowering stage (R₂) of the crop. The peak incidence of larva, pupa and adult could be noticed in the month of March or early part of April, when the crop was at fruit maturation and ripening stage (R₄ and R₅). Soon thereafter, the population declined within three to four weeks during last stages of the crop (R₆ and R₇). A study of seasonal abundance of *H. vigintioctopunctata* on solanaceous host plants in Punjab done by Ranzan *et al.* (1990) revealed that the

population peak of the beetle was attained in the month of March, which is in agreement with the present finding. However, Raj *et al.* (1980) recorded their peak on brinjal during January in Tamil Nadu. It was also evident from the present investigation that the number of egg clusters in the field declined, when the population of larvae, pupae and adults increased. Similar findings on this regard were also reported by Hirano (1985). Nakamura (1976, 1988) suggested that the cause of population decline in the later part of the crop stage was due to egg cannibalism, competition for food among larvae or unsuitable leaf quality for the coccinellids. Regarding appearance of *H. vigintioctopunctata*, he reported that the pest appeared in the field soon after planting of the brinjal crop.

In the present investigation, initial population of *H. vigintioctopunctata* was low during both 1998 – 99 (0.40 larvae/plant and 0.43 adults/plant) and 1999-2000 (0.20 egg clusters/plant and 0.23 adults/plant) cropping seasons. The population of this insect was quite low and sparse upto the month of January during both the years. Their population shoot up to a high level of 23.20 larvae, 8.13 pupae and 3.53 adults per two branches during the month of March in 1998-99. The peak population of *H. vigintioctopunctata* (11.80 larvae, 5.20 pupae and 2.86 adults per two branches) during second year (1999-2000) was also recorded in the month of March. The population reached peak, when the crop was at fruit maturation and ripening stage (R_4 and R_5) in both the years. During this stage of the crop, the plants were also flushing afresh, which might be a probable cause of their outbreak. Raj *et al.* (1980) reported the peak larval and adult population of *H. vigintioctopunctata* on brinjal to be 99 and 226 per 100 leaves, respectively. According to Ramzan *et al.* (1990), the highest density of this pest was 526.3/10 plants

recorded on *Solanum xanthocarpum* in March. However, the beetle population in the second year was quite low in comparison to the first year. Very high infestation of red spider mite, *Tetranychus neocaledonicus* during the second year cropping season could be one of the possible reasons for their low infestation on brinjal crop, as because both mites and the coccinellids preferred brinjal as their principal host, but in the first year mite infestation was negligible.

5.2.1 Impact of natural enemies on *H. vigintioctopunctata* population

In the present investigation, the coccinellid beetle, *H. vigintioctopunctata* was parasitized by two species of hymenopteran parasitoids of the family Eulophidae viz., *Tetrastichus* sp. and *Pediobius foveolatus* Craw. *Tetrastichus* sp. primarily parasitized the eggs but were also found to parasitize the first and second instar larvae, while *P. foveolatus* was found to parasitize the third and fourth instar larvae and pupae. Both these parasitoids were earlier recorded from India (Rajendran and Gopalan, 1997; Raghuraman and Veeravel, 1999) and Sumatra (Abbas and Nakamura, 1985; Nakamura *et al.*, 1988). The extent of parasitization of *H. vigintioctopunctata* eggs by *Tetrastichus* sp. varied from 6.95 – 35.70 per cent and 7.00 – 43.75 per cent during 1998 – 99 and 1999 – 2000, respectively. While the parasitization of larvae by the parasitoid varied from 6.60 – 38.90 per cent in the first year and 15.00 – 24.20 per cent in the second year. This observation was almost in agreement with the results obtained by Abbas and Nakamura (1985). However, slightly low parasitization of eggs could be due to differences in egg deposition by both host and parasitoid, which might have interfered their relationships. There were significant positive correlations between population

density of egg clusters and extent of parasitization by the parasitoid in the second year and between larval population and extent of parasitization in both the years. The extent of parasitization of larvae and pupae of the beetle ranged from 3.10 – 22.20 per cent for larvae and 16.60 – 47.50 per cent for pupae during 1998 – 99; and 8.60 – 18.50 per cent for larvae and 8.30 – 31.70 per cent for pupae during 1999 – 2000. The present observation was in accordance with the reports of Abbas and Nakamura (1985) and Rajendran and Gopalan (1997). Former recorded 1.2 – 19.4 per cent parasitization of larvae and 59.1 per cent of pupae by *P. foveolatus*, while the latter recorded 47.1 – 49.5 per cent parasitization of the pupae of *H. vigintioctopunctata*. The extent of parasitization showed significant positive correlation with the larval population during the first year and with the pupal population in both the years of investigation.

During the course of the present study, no predator of any of the stages of the beetle could be noticed in the field.

5.2.2 Impact of meteorological factors on *H. vigintioctopunctata* population

Temperature (maximum and minimum) showed non-significant relationship with the population of all stages of the beetle in both the cropping seasons. Both maximum and minimum temperatures were to some extent responsible for the increase in larval, pupal and adult population of the beetle. Devi (1988) reported that temperatures had positive effect on population of coccinellids.

Relative humidity exhibited negative correlation with the population of *H. vigintioctopunctata* during 1998-99 and 1999-2000. However, significant negative

effects were shown by morning relative humidity with the larval, pupal and adult populations of the coccinellid in both the years.

Rainfall and number of rainy days had no direct effect on the population, although to some extent had negative association with the beetle population in both the years.

However, the results of the present investigation were contradictory to the findings of Devi (1988).

Bright sunshine hours showed non-significant negative association with the population of *H. vigintioctopunctata* during 1998 – 99, but exhibited non-significant positive effect on the population of the beetles during 1999-2000. Such positive association was also reported by Devi (1988) on *Henosepilachna dodecastigma* Wied in soybean during summer.

5.3 Predatory efficiency of coccinellid predators on *A. gossypii*

Laboratory studies concerning predatory efficiency of *C. repanda*, *M. sexmaculatus* and *M. discolor* on *A. gossypii* showed significant difference at $P = 0.01$.

The predatory efficiencies of *C. repanda* were 100.00, 100.00, 87.78, 74.90 and 59.70 per cent when offered 10, 20, 30, 40 and 50 aphids, respectively. Consequently, the consumption rates were 10, 20, 26.33, 29.96, 29.85 aphids/24 h. It showed increase in the feeding rate of the coccinellid predator with the increase in density of the available prey. It is because of the fact that there might be an easy access for the predator to locate preys. Saharia (1981) recorded a moderate efficiency (44%) of *C. repanda* when offered *L.*

erysimi as prey. Barman (1992) also tested the predatory efficiency of *C. repanda* on *A. craccivora* and found this efficiency to be 48.27 per cent.

Predatory efficiencies of *M. sexmaculatus* were 100.00, 79.44, 54.80, 41.39 and 33.11 per cent, when offered 10, 20, 30, 40 and 50 numbers of *A. gossypii*, respectively. The consumption rates were 10, 15.88, 16.44, 16.55 and 16.55 aphids/24 h, respectively. Palaniswami and Pillai (1981) also recorded similar consumption rate by the coccinellid on *A. gossypii*.

Predatory efficiencies of *M. discolor* were observed to be 100.00, 56.11, 40.37, 30.28 and 25.44 with a consumption rate of 10, 11.22, 12.11, 12.11 and 12.72 aphids/24h, when offered 10, 20, 30, 40 and 50 numbers of *A. gossypii*. Similar observations were recorded by Barman (1992), while studying with *A. craccivora*. The consumption rates obtained in the present study were in conformity with the records of Palaniswami and Pillai (1981).

5.4 Distribution pattern of *A. gossypii*

5.4.1 Distribution pattern of *A. gossypii* nymphs

The nymphs of *A. gossypii* appeared in the field, during the second week of October for the first year crop and during second week of November for the second year crop, when the crop was in seedling (S_3) stage. The population rose to peak in R_2 or R_3 stage (flowering or fruit initiation) in the fourth week of January during first year and in the fourth week of February during second year. The variance to mean ratios were greater than unity for most of the sampling occasions, which signified clumped type of distribution. However, low values of such ratios (< 1) obtained in both plant inspection

methods [PI(A) – 1 and PI (A) – 2] in the first two sampling dates during first year indicated regularity of distribution. The values of exponent-k were less than eight for most of the cases except a few observations in the first year, which signified that the nymphal populations were aggregated in nature. Higher 'k' values (> 8) indicated that clumping was low and it was also evident from the higher mean population data in the first year. These observations were in agreement with the observations of Denechere (1981), and Nath and Nag (1996). Similarly, the values obtained by David and Moore's index of dispersion, Lloyd's index of mean crowding and patchiness, and mean colony size also confirmed clumped distribution of nymphs in most of the cases. The values of mean clump size were greater than two in almost all the sampling dates indicated that the clumping was due to environmental heterogeneity in the brinjal plots and active behaviour of *A. gossypii* nymphs. The environmental heterogeneity might be due to non-uniformity of plant growth and leaf quality. Singh *et al.* (1990) made an opinion that environmental heterogeneity at low population and innate behaviour of *A. gossypii* at high population, were responsible for the aggregated dispersion of the species. Similar results were also reported by Barman and Dutta (1997) on *A. craccivora* in green gram.

Iwao's patchiness regression and Taylor's power law models showed that nymphal population of *A. gossypii* was distributed in an aggregated manner in both the years of investigation. Similar pattern of distribution of *A. gossypii* was reported by Zhang *et al.* (1998) on cotton in China, Burgio *et al.* (1994) on cucumber and melon in Italy and Trumble *et al.* (1983) on winter strawberry in coastal California.

In addition, the present findings also agreed with the findings of Vergara and Galeano (1994) on *A. gossypii* in cotton and Edelson (1986) in cantaloupe.

5.4.2 Distribution pattern of *A. gossypii* adults

The adults of *A. gossypii* appeared in the crop during the second week of October in 1998 – 99 and during the second week of November in 1999 – 2000. The population of apterous adults reached their peak in the third week of January in the first year and third week of February in the second year, when the crop was at flowering (R_2) and fruit initiation (R_3) stage, respectively. While population of alate adults reached their peak in the first or second week of April at the last reproductive (R_7) stage of the crop, when crop growth ceased in both the years. Except one or two initial sampling dates, the variance to mean ratios were greater than unity in both plant inspection methods, which indicated aggregated dispersion of the adult population. This type of distribution can be described by the mean and exponent- k for measuring the amount of clumping. 'k' values greater than eight were observed only in few cases in respect of apterous adults in the first year and remaining all other cases including alate adults, 'k' values were less than eight indicating high amount of aggregation. The higher values of 'k' (>8) found in some apterous populations in all the sampling methods were due to higher population density of the adults. This finding clearly agreed with the reports of Kuno (1980) and Evans (1982). Denechere (1981) found that population of *A. gossypii* had an aggregated distribution on cotton plants that was determined by negative binomial law. The values of David and Moore's index of clumping were positive in all the possible cases, Lloyd's mean crowding index greater than mean population density and patchiness index greater

than unity, almost confirmed the contagious nature of dispersion of both alate and apterous adults. Mean colony size further confirmed the clumping nature of the aphid population. Mean clump size computed for adults showed that clumpings were mainly due to environmental heterogeneity in the brinjal plots as well as innate behaviour of the adults in most of the cases, while in half of the cases related to alate adults' clumping was governed by innate behaviour of the alatae. Similar findings were also reported by Singh *et al.* (1990) and, Barman and Dutta (1997).

Iwao's patchiness regression and Taylor's power law models also indicated aggregated distribution of both alatae and apterae of *A. gossypii* adults. Similar reports were also made by Zhang *et al.* (1998) and Trumble *et al.* (1983).

5.5 Distribution pattern of *H. vigintioctopunctata*

5.5.1 Distribution pattern of immature stages of *H. vigintioctopunctata*

Among the immature stages of *H. vigintioctopunctata*, the larval stage was first noticed in the field during second week of October, 1998-99; and the egg stage during fourth week of November, 1999-2000, when the crop was at seedling (S₃) stage. The egg cluster counts were maximum during fruit initiation (R₃) stage in the first week of February and first week of March for first and second year crop, respectively. Larvae attained their peak population in between first and fourth week of March at R₄ and R₅ stage (fruit maturation and fruit ripening) of the crop, whereas pupae population reached their peak at the fruit ripening (R₅) stage of the crop during third or fourth week of March. The variance to mean ratios indicated clumped distribution in most of the sampling dates. However, in a few initial and later stages of the crop, all the immature

stages showed regularity in distribution. It was clearly indicated by the low population density of egg clusters, larvae and pupae at both initial and later stages of the crop. Anscombe (1961) stated that distribution of an insect varied with the variation of its population level. Low populations were distributed randomly or regularly, while high population had a tendency to become aggregated. The values of exponent-k were less than eight except in one or two cases of larval and pupal count, which signified high amount of clumping for population of all the immature stages. The present findings were in conformity with the reports made by Suman *et al.* (1987), however, they reported that egg masses were distributed randomly with a tendency towards aggregation at high densities. The values of David and Moore's index of clumping also indicated similar results. The values of Lloyd's indices of mean crowding were greater than mean population densities in majority of the cases for all the immature stages, signifying contagious nature of dispersion. The values of the indices less than unity were, however, observed in case of egg cluster counts in both the years, which indicated that at lower population densities, the egg clusters followed random dispersion with a slight tendency towards aggregation when density increased. These indices showed higher values than unity for almost all the larval and pupal stages in both the years of sampling. Lloyd's index of patchiness and mean colony size values further confirmed the results obtained by earlier methods. The stability of these indices for all the immature stages at different population densities in both the years indicated that the populations of egg, larva and pupa tend to remain together. The cause of clumping of egg masses was micro-environmental heterogeneity in the brinjal plots, whereas clumpings in the case of larval and pupal population were due to both environmental heterogeneity as well as innate

behaviour of the larvae, as evident from the values of mean clump size. Environmental heterogeneity might occur due to non-uniformity of crop growth, which possibly affected regularity in oviposition. Taylor (1961) explained that the main cause of aggregation appeared to be a result of the oviposition behaviour of female since eggs are laid in clusters.

Further confirmation of the results of aggregation was brought about by the models of Iwao's patchiness regression and Taylor's power law for all the immature stages of *H. vigintioctopunctata*, during 1998 - 99 and 1999 - 2000.

In the present investigation, all the immature stages of *H. vigintioctopunctata* followed negative binomial distribution, while egg masses showed some affinity towards poisson distribution. Suman *et al.* (1987) described contagious distribution of *H. vigintioctopunctata* larvae and pupae on brinjal, which was in conformity with the present findings.

5.5.2 Distribution pattern of *H. vigintioctopunctata* adults

The adults of *H. vigintioctopunctata* made their appearance in the second week of October during 1998 - 99 and fourth week of November during 1999-2000, when the crop was in seedling (S₃) stage. Their population rose to peak in the R₅ stage (fruit ripening) during the third or fourth week of March. The variance to mean ratios for adult populations were invariably greater than unity on all the sampling dates except in few occasions at the seedling and flowering initiation stage of the crop during first year, indicating contagiousness of distribution. The values of exponent-k were less than eight in majority of the cases, which indicated high degree of clumping among adults in both

the years. However, adult populations had a tendency to become regularly distributed at higher population densities. Kuno (1980) and Evans (1982) opined that exponent-k, which measures the amount of clumping, was influenced by the sizes of population of the insects. Expectedly, the values of David and Moore's index of clumping, Lloyd's indices of mean crowding and patchiness, and mean colony size contributed similar results, describing the contagious nature of distribution of the adults. The mean clump size computed for adults showed that micro-environmental heterogeneity at low population density of adults and both environmental heterogeneity and active behaviour of adults at higher densities might be the causes of clumping. The environmental heterogeneity might have occurred due to the non-uniformity of the crop growth resulting in differences in canopy thickness and height, which might have led to differential preference of adults to plants for sheltering and feeding. Reports of Singh *et al.* (1990) on density dependant clumped distribution of *A. gossypii* fairly agreed with the present findings on *H. vigintioctopunctata* adults.

Iwao's patchiness regression and Taylor's power law models also confirmed the aggregated distribution of *H. vigintioctopunctata* adults.

Earlier, Saikia and Dutta (1994) reported that *Riptortus linearis* (Fabr.) adults followed clumped distribution on greengram. Borah (1997) also found that the adults of *Megacopta cribrarium* (Fab.) followed negative binomial distribution on pigeonpea. The present findings are in conformity with these reports.

5.6 Optimum sample number

Optimum number of samples need to be drawn for estimating pest population depends on expected frequency of population density of insects and accurate desired levels of precision. This could only be possible through extensive preliminary information on the distribution pattern and the population density of the insects.

Ruesink's model (1980) was used to compute the optimum number of samples required to be drawn in plant inspection methods with two levels of precision ($C = 0.10$ and $C = 0.25$). The optimum number of samples required for ecological studies of *A. gossypii* nymphs and adults during 1998 -- 99 were 38 and 32 (nymphs) and 37 and 35 (adults) under sampling method PI(A)-1 and PI(A)-2, respectively. For pest management studies it numbered 6 and 5 for both nymphs and adults under PI(A)-1 and PI(A)-2, respectively. However, optimum sample numbers required during 1999 -- 2000 for this pest increased 4 – 5 times than the previous year for both sampling methods. The increase in optimum sample number was due to low population density of aphids as well as high degree of clumping shown by the aphid population.

The optimum sample numbers (average of two years data) required for ecological studies of *H. vigintioctopunctata* egg clusters (196 and 172), larvae (196 and 131), pupae (216 and 143) and adults (285 and 196) under PI(L)-1 and PI(L)-2 sampling methods, respectively. For pest management studies, the optimum number of samples would be 35 and 29 for egg clusters, 37 and 21 for larvae, 35 and 24 for pupae, and 47 and 32 for adults in these two methods of sampling, respectively. However, there was no large difference of sample numbers in both the years except sample numbers for adults and egg

clusters at 10 per cent precision level. The increased number of optimum samples for adults and egg cluster counts during 1999 – 2000 was due to aggregated pattern of distribution and low population density of the adults.

5.7 Varietal resistance

Sixteen brinjal varieties were evaluated for resistance against *A. gossypii* and *H. vigintioctopunctata* based on natural infestation under field conditions as well as developmental and reproductive parameters under laboratory conditions. In addition, physical and biochemical characters of leaves of brinjal varieties were determined to ascertain their possible association with infestation and biological parameters of these insects.

5.7.1 Infestation of *A. gossypii*

Infestation parameters such as intensity of attack and population density of *A. gossypii* on brinjal varieties showed significant differences. Intensity of attack significantly varied among varieties during the last part of January, when the infestation was at its peak in all the varieties. Varieties also had significant influence on the seasonal mean intensity. In respect of population density of the pest, varieties showed significant difference during entire study period including seasonal mean densities. The differential response of the varieties to the attack of aphids indicated the existence of resistance mechanism in the plants. Painter (1951) stated that the heritable qualities possessed by plants influenced the ultimate degree of damage done by the insect. These inherent qualities were specific to the variety, which implied existence of a resistance mechanism in the plant. On the basis of intensity, variety Neelam Long was found to be most

susceptible to aphid attack. While the varieties Aruna and 'Kharua Bengena' were least preferred. These two varieties showed similar response in respect of aphid population density also, which confirmed their unsuitability to aphid attack. For a critical examination of varietal resistance, population density was considered to be the basis of ranking brinjal varieties against *A. gossypii*. Aruna and 'Kharua Bengena' were ranked as resistant; Pant Samrat, KS-331 and Pusa Bindu were categorized as moderately resistant; Arka Nidhi, Pusa Kranti, AB-2, Arka Keshav and Pusa Bhairav were moderately susceptible, while the rest of the varieties were susceptible. Earlier, Reddy and Biradar (1990) and Jyani *et al.* (1995) evaluated resistance of brinjal varieties against *A. gossypii* on the basis of population density in the field condition and reported that locally available brinjal varieties showed resistance to some extent in comparison to other promising varieties. Kennedy and Kishaba (1977) reported that resistant plants exerted moderate arrestant effect on aphids. The weaker arrestant effects of resistant than susceptible plants resulted in greater interplant movement of aphids.

5.7.2 Infestation of *H. vigintioctopunctata*

Extent of leaf infestation by *H. vigintioctopunctata* differed significantly among varieties only in two occasions, when intensity of attack was around its highest. While in respect of population density, varieties showed significant differences in all the dates of observation. Seasonal means were found to be significantly different among varieties. Between two infestation parameters, population density was considered to be the criterion for ranking brinjal varieties against *H. vigintioctopunctata*, because it had significant influence on varieties in all sampling occasions. On the other hand, it has higher degree

of precisions than intensity in evaluating plant varieties. Results of both the infestation parameters revealed Pusa Purple Long, Pusa Bindu, Pusa Uttam, JC-2 and Pusa Bhairav as the most susceptible ones averaging the higher intensity of attack and higher population densities of aphids. While variety 'Kharua Bengena' once again proved to be the most unsuitable also for the beetles, registering the lowest population density and was ranked as resistant. Varieties Aruna, KS-331, Pant Samrat, 'Sagalisingia', Muktakeshi and Pusa Kranti were categorized as moderately resistant. The remaining varieties were adjudged as moderately susceptible. According to Raj and Kumaraswami (1979), Pusa Purple Long was a highly susceptible variety and Pusa Kranti a moderately resistant one, as tested on the basis of feeding scores. Similarly, Ganga and Nagappan (1982), Sambandam *et al.* (1974) and Rajendran and Gopalan (1997, 98) evaluated resistance of brinjal varieties based on feeding scores. Data on leaf area consumption by this pest (Section 4.13.3) also confirmed these observations.

5.7.3 Varietal effect on biological parameters of *A. gossypii*

5.7.3.1. Developmental parameters

Total nymphal periods of *A. gossypii* were shorter in susceptible varieties JC-2, Pusa Purple Long, 'Sagalisingia', Pusa Uttam, Neelam Long and Muktakeshi. Moderately susceptible varieties Pusa Bhairav, AB-2, Arka Keshav, Pusa Kranti and Arka Nidhi also exhibited short nymphal periods. However, this period was longest in resistant varieties 'Kharua Bengena' and Aruna. The trend was similar for nymphal survival also as the survival was maximum in susceptible varieties and minimum in resistant varieties. Faster development in susceptible varieties might be due to their

nutritional superiority or due to lack of antixenosis factor or due to absence or lower presence of antibiosis factor. Results of similar nature were earlier reported by Ekukote (1990), Kennedy and Kishaba (1977) and Klingler *et al.* (1998) on *A. gossypii*. The differences of nymphal development among the varieties were contributed only by the first instar duration and remaining nymphal instars were not evidently affected by the varieties.

The variation in first instar duration in different varieties might be due to antixenosis or antibiosis based effects. As the first instar nymphs are to move over the plant surface for selection of feeding sites and settlement for feeding, they might have encountered different kinds of interference in locomotion and feeding on plant surfaces of different varieties. Norris and Kogan (1980) stated that physical and chemical characteristics of plant interferes with locomotion, feeding, ingestion and oviposition of insects. Das (1999) reported similar findings on *A. craccivora*.

5.7.3.2 Reproductive parameters and adult longevity

The varieties tested did not significantly affect the reproductive and post-reproductive periods, and fecundity of *A. gossypii*. Pre-reproductive period and rate of nymphal deposition by female differed among varieties. Adult female aphids awaited longer in resistant ('Kharua Bengena' and Aruna) and moderately resistant (KS-331 and Pant Samrat) varieties, while it took shorter periods before deposition of nymphs to the susceptible varieties. The susceptible varieties also accounted for higher rate of nymphal deposition by female adults. On the other hand, the resistant and moderately resistant varieties like Aruna, 'Kharua Bengena' and Pant Samrat reduced the rate of deposition of

nymphs. The reduced nymphal deposition rates of *A. gossypii* on resistant varieties might be due to either non-preference for nymphal deposition sites, nutritional deficiency, pilosity or plant biochemical defence factors. Findings of similar nature were also reported by Hill (1983), Dariev *et al.* (1979), Wang (1983), and Banerjee and Raychaudhuri (1987).

5.7.4 Varietal effects on biological parameters of *H. vigintioctopunctata*

5.7.4.1 Developmental parameters

Incubation period of *H. vigintioctopunctata* eggs was longer when reared on resistant, moderately resistant and moderately susceptible varieties. However, among susceptible varieties, Pusa Purple Long, Pusa Bindu, JC-2 and Pusa Bhairav had shorter incubation periods. Larval development was delayed by resistant variety 'Kharua Bengena'. Moderately resistant varieties like Pant Samrat, Aruna, Pusa Kranti and Muktakeshi also lengthened the larval period of *H. vigintioctopunctata*. Among the susceptible varieties, Pusa Bindu and Pusa Purple Long favoured quicker larval development. Similarly, 'Kharua Bengena', Aruna, Muktakeshi, KS-331 and Pant Samrat delayed pupal development, while shorter pupal periods were recorded in susceptible and moderately susceptible varieties. Longer duration of development in resistant varieties might be due to insufficient nutrient intake by the beetles or unfavourable physical and biochemical factors of the varieties. Similar nature of results were also reported by Sachan and Rathore (1979), Ramzan *et al.* (1990) and Phukan (1976) on solanaceous plants. The hatchability of eggs in the resistant variety was reduced by 24 – 32 per cent from that of the susceptible varieties. The larval survival was low in resistant and

moderately resistant varieties while higher larval survival were recorded in susceptible varieties. Similarly, per cent emergence of adults was more in susceptible varieties than in the other varieties. Growth index was lowest in Aruna (2.26) followed by KS-331 (2.43) and 'Kharua Bengena' (2.48) and highest in Pusa Bindu (6.17) followed by Pusa Purple Long (5.78). Results of similar nature were obtained by Patil *et al.* (1986) on fruit borer, *Earias vittella* Stoll, in okra. They found that the growth and development of the borer were retarded in resistant varieties, which might be due to the presence of antibiosis mechanism in the plant. Das (1999) also observed identical trends of growth index of *Nacoleia vulgalis* Guen. on greengram varieties. Borah (1977) also recorded similar results with *H. vigintioctopunctata* on different cucurbitaceous hosts.

5.7.4.2 Reproductive parameters, adult longevity and sex ratio

In resistant and moderately resistant brinjal varieties, the adults of *H. vigintioctopunctata* remained in copulation for brief periods. Pre-oviposition period of *H. vigintioctopunctata* was lengthened in resistant and moderately resistant varieties. Adults preferred leaves of susceptible varieties like Pusa Bindu, JC-2 and Pusa Purple Long to oviposit where fecundity was maximum, whereas, lower fecundities were recorded on some resistant and moderately resistant varieties. Similarly, reproductive rates were higher in susceptible varieties and lower in resistant varieties. In resistant variety 'Kharua Bengena' and moderately resistant varieties 'Sagalisingia', Aruna and KS-331, the sex ratios of *H. vigintioctopunctata* were more than 2 males : 1 female while in susceptible varieties, the ratios were less than 1.5 males : 1 female under laboratory conditions. However, the sex ratios of field population did not differ significantly among

varieties; the ratios being almost 1:1. The equal proportion of the sexes in natural conditions might be due to the fact that in the open field, the male and female population had a better chance to mix up, compared to the confined condition of the laboratory, where the males were proportionally more. Sachan and Rathore (1979) also evaluated that pre-oviposition, oviposition and post-oviposition periods of *H. vigintioctopunctata* varied with different solanaceous host. These were longest on resistant and shortest on susceptible hosts. More numbers of males than females were reported to emerge on resistant host plants. Phukan (1976) found that fecundity of this beetle was more and adults lived longer when fed on susceptible solanaceous hosts than on resistant ones.

5.7.4.3 Leaf area consumption by *H. vigintioctopunctata*

Brinjal varieties showed significant differences in regards to leaf area consumption by larvae and adults of *H. vigintioctopunctata*. It was also apparent that adults consumed more area of leaf tissues than larvae does in first 48 h of their emergence. In this single choice test, the mean leaf area consumption by a single larva (7.68 cm²/48 h) or an adult (20.20 cm²/48h) was measured maximum in Pusa Bindu, whereas, 'Kharua Bengena' registered minimum leaf area consumption by both the larva (1.99 cm²/48 h) and the adult (5.08 cm²/48 h). Varieties like Pusa Purple Long, Pusa Utam, Pusa Bhairav and JC-2 were also considered favourable for their feeding. This preferential consumption on brinjal leaves of different variety was also evident from shorter duration of development from egg to adult, higher adult emergence and higher growth index of this pest. In these susceptible and moderately susceptible varieties, larval survival was also high and the larvae were observed to feed on the leaves almost

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continuously, forming skeletonized patches. The leaf area consumption by larvae and adults in the present study were almost in agreement with the results obtained by Borah (1977) and Imura and Ninomiya (1998) with this species on different solanaceous and cucurbitaceous hosts. In addition, Vasantha *et al.* (1986) and Rufener *et al.* (1987) also reported that larvae of *H. vigintioctopunctata* fed continuously on susceptible host leaves, consumed larger amounts of leaf material, had faster rate of development and low mortality rates than the larvae exposed to the resistant lines. The less consumption rates in resistant varieties recorded in the present study might be due to host morphology or presence of plant allelochemicals in large quantities or due to lack of nutrition.

5.8 Mechanism of resistance

Brinjal varieties exerted significant effects on development and reproduction, and numerical abundance of *A. gossypii* and *H. vigintioctopunctata*. Among the brinjal varieties 'Kharua Bengena' showed its supremacy in deterring both the pests and exerted effects on several biological parameters. However, Pusa Purple Long, Pusa Uttam and JC-2 were mostly preferred by these pests as evident from their shorter developmental period, longer reproductive period and higher fecundity, and higher field population densities.

Studies on the morphological and biochemical characters of the varieties revealed that antixenosis factors had no apparent effect on any aspect of the biology and population of *A. gossypii*. However, higher 'K' content, higher moisture content and lower carbohydrate content in leaves of resistant and moderately resistant varieties significantly affected different life parameters of the aphid. Moderately resistant varieties,

Pusa Bindu, Pant Samrat, Aruna and KS-331 recorded higher leaf moisture and 'K' contents. 'Kharua Bengena', the aphid resistant variety had the lowest carbohydrate content and due to this probable reason, it was unsuitable for their consumption. This supported the earlier works of Allen *et al.* (1957), who reported that there is a distinct relationship between 'K' content and availability of carbohydrate in the plant. The potassium deficient plants were mostly preferred by aphids. 'K' helps in formation and translocation of carbohydrates, cell division and water relations in plants (Chakraborty, 1999), which in turn might confer resistance against aphids. The population density of *A. gossypii* was significantly affected by low moisture content in leaves of 'Kharua Bengena'. Low moisture content of leaf has been opined to be a major evolutionary hurdle for phytophagous insects (Southwood, 1978). Similarly, Edward and Wratten (1980) also stated that reduced water supply acts indirectly on insects by changing the nitrogen balance in plants. This criterion might also be applicable in the present findings. Overall analysis of the facts reveals that leaf moisture, 'K' content and carbohydrate content play a primary role in deciding the suitability of varieties to *A. gossypii*. The varieties differed in respect of several morphological traits. However, these were not found to be significantly related to resistance of the varieties to aphids. Though in the present study, none of the morphological and other biochemical plant characters showed any significant association with resistance, however, their involvement in conferring resistance was earlier shown by several workers. Leaf pilosity (Hill, 1983; Levin, 1973; Gilbert, 1971; Dariev *et al.*, 1979; Negm *et al.*, 1980) and leaf colour (Pathak, 1961) are known to be associated with resistance to aphid. Total nitrogen content (McGarr, 1942; Benerjee and Raychaudhuri, 1987), amino acid content (Hill, 1983) and crude protein

content (Davis, 1972; Shvetsova and Alibekova, 1984) were also reported to be associated with aphid resistance. Their proportional differences rather than quantitative variations of a particular constituent are probably more important in deciding varietal suitability.

Brinjal varieties also showed marked variations in respect of developmental period, reproduction, sex ratio, adult longevity and field population level of *H. vigintioctopunctata*. Thus, variation in these parameters indicated an impending condition of the host plant therein. Positive significant correlation between the leaf area and rate of oviposition of the adults appeared to show a preferential response of the beetle to bigger area of young and medium aged leaves for oviposition. Larger and young or medium aged leaves could produce sufficient space and adequate nutrition for newly emerged larvae to feed on. Again, the variation in response to red colour component of the leaves indicated that more the red colour, shorter were the larval and pupal periods; longer the adult longevity, higher the fecundity and rate of oviposition. Variety Pusa Bindu had the highest red and blue colour components in leaves and was found to be the most susceptible variety to *H. vigintioctopunctata*. Herrera and Muniz (1979) reported that *Epilachna varivestis* Muls. preferred red colour, which is a favourable colour next to black. Present findings agree with this report. However, Saxena (1973) reported that as the leaves of many preferred and non-preferred plants are almost of the same colour, doubts are sometimes that plant colour would be a non-specific stimulus, which cannot provide a strong cue to insects for discrimination among plants.

Brinjal varieties exhibited variations in leaf biochemical contents. Only tannin and total phenol contents were significantly correlated with population density, certain reproductive parameters and sex ratio of *H. vigintioctopunctata*. The tannin content of leaf had significant negative effect on population density and rate of oviposition, and was positively correlated with sex ratio. High levels of tannin were found in the varieties 'Kharua Bengena', KS-331 and 'Sagalisingia', which appeared to be less preferred by the beetle. However, less tannin contents were found on Pusa varieties. Swain (1979) opined that higher tannins in plants afford defence to herbivores by reducing nutritional availability of soluble protein and polysaccharides. Further, the activities of digestive enzymes and symbiotic micro-organisms in the herbivores own gut are said to be impaired. The involvement of tannin in offering resistance to brinjal varieties against *H. vigintioctopunctata* could also be explained on these possible lines. Results of similar nature were also reported by Ishaaya (1986) and Borah (1987).

Phenol content of leaves showed significant negative correlation with population density and certain reproductive parameters of *H. vigintioctopunctata*. The present investigation revealed that the favourable hosts Pusa varieties, Arka varieties and variety Neelam Long were contained lower amount of phenol as compared to 'Kharua Bengena' (resistant) and other moderately resistant varieties. The role of phenols in imparting resistance to *H. vigintioctopunctata* might be due to complex interactions, which could activate host chemical defence. Results of similar nature were reported by Raju *et al.* (1987) and Sambandam *et al.* (1976), who observed that high amount of phenols of the brinjal leaves were implicated with the resistance of varieties to the beetle. Dutta (1984)

also reported that phenols are known to be a factor for antibiosis in sugarcane varieties against the scale insect, *Melanapsis glomerata* (Green).

Many of the plant morphological and biochemical characters, which were earlier reported to be associated with host resistance, were not significantly correlated with the infestation and life parameters of the beetle in the present investigation. These characters that were shown to impart resistance were leaf pilosity (Phukan, 1976; Levin, 1973; Gilbert, 1971), crude protein (Phukan, 1976; Ganga and Nagappan, 1983) and leaf moisture content (Edward and Wratten, 1980).

Literature presents a rather hazy picture of the actual mechanism of resistance of brinjal to *A. gossypii* and *H. vigintioctopunctata*, which makes it difficult to make any conclusive remark about the exact role of plant characters either physical, biochemical or their combination in conferring resistance. Among the physical plant characters, leaf pilosity was shown to confer resistance against *A. gossypii* (Dariev *et al.*, 1979; Wang, 1983) and *H. vigintioctopunctata* (Phukan, 1976). Other physical characters like thick cortex (Quiras *et al.*, 1977) and dark green coloured leaves (Pathak, 1961) were linked up with resistance against *A. gossypii*. Differences in biochemical constituents of the host plants were also shown to be the probable causes of resistance to *A. gossypii* and *H. vigintioctopunctata*. It is reported that in resistant cowpea varieties, aphids suffered mortality due to higher total carbohydrate, soluble sugar and Ca^{++} ion (Negm *et al.*, 1980). Some cotton varieties showed resistance to *A. gossypii* because of protein heterogeneity and proteinase activity (Shvetsova and Alibekova, 1984). Water supply in this regard might have a role as it acts indirectly on insects by changing nitrogen balance

(Edward and Wratten, 1980), while according to Wearing (1972) intermittent water stress is also an important factor governing resistance against aphids. Moreover, Turner (1971) found that the growth of *A. gossypii* is hindered due to absence of certain essential amino acids especially methionine. As regards host plant resistance to *H. vigintioctopunctata*, Raju *et al.* (1987) reported that low nitrogen and potassium content, and higher phosphorus, total carbohydrate and phenol content in brinjal varieties are prerequisites for showing resistance to this pest. According to Sambandam *et al.* (1976), high reducing and non-reducing sugars, chlorophyll, phosphorus and total phenol contents actually confers resistance to brinjal varieties against *H. vigintioctopunctata*. Although the association of these various plant morphological and biochemical characters to resistance against these pests has been recorded in the past works, precise details of the resistance mechanisms in these cases are not clearly known.

In the present investigation also various antixenosis and antibiosis based factors were examined. Some of these factors were found to have associated with infestation and various life parameters of these pests, although many of the associations were not significant statistically. Such factors, which could be involved in resistance against *H. vigintioctopunctata* are foliage density, stomatal density and leaf pilosity. On the other hand, leaf pilosity, angle of leaf attachment, veinlet density and stomatal density could have some role in determining resistance against *A. gossypii*. Among the biochemical factors that could contribute towards resistance against *A. gossypii* are tannin, total phenol and total free amino acid; while crude protein, potassium and total carbohydrate might have associated with resistance against *H. vigintioctopunctata*. Further study in

greater detail regarding the association of these physical and biochemical traits and by involving more numbers of brinjal varieties/germplasms would reveal more precise information on resistance against these two pests.

The present study on the population ecology and varietal preference of *A. gossypii* and *H. vigintioctopunctata* on brinjal brought out several new information on the seasonal history, population dynamics, distribution pattern, optimum sample numbers and varietal resistance. These first hand information, under the prevailing climatic conditions of Assam would serve as base line for further study aimed at management of these pests. The spatial distribution pattern of *A. gossypii* on brinjal has been studied for the first time in India. Some potentially active natural enemies like *C. repanda* and *M. sexmaculatus* predating on *A. gossypii*, and parasitoids like *Tetrastichus* sp. and *P. foveolatus* parasitizing eggs, larvae and pupae of *H. vigintioctopunctata* have been reported to regulate the natural populations of these pests. These biocontrol agents could be incorporated into future pest management programmes against these two pests. The optimum sample numbers estimated in the present study could be adopted for accurate estimation of population of these two pests by future researchers, who want to work on their ecological and pest management aspects.

Varietal preference studies revealed that the resistant and moderately resistant varieties against *A. gossypii*, such as 'Kharua Bengena', Aruna, KS-331, Pant Samrat and Pusa Bindu contained higher amount of 'K' and leaf moisture, and lower carbohydrate content. Hence, in future breeding programmes to evolve aphid resistant brinjal varieties, these varieties could be used as one of the parents for crossing with agronomically

suitable varieties. Selection of varieties may also be made on the above varietal characters. As regards resistance against *H. vigintioctopunctata*, the resistant and moderately resistant varieties like 'Kharua Bengena', Aruna, KS-331, Pant Samrat, 'Sagalisingia', Muktakeshi and Pusa Kranti possessed plant characters, such as smaller leaf area, lighter red colour component of leaf, higher tannin and total phenol contents. Thus, these varieties may be made use of by breeders in resistance breeding programmes against *H. vigintioctopunctata*. Varieties may also be selected on the basis of these plant characters.

Thus the present study has revealed that brinjal variety 'Kharua Bengena' is resistant against both these economically important pests of brinjal. However, other varieties like Aruna, KS-331, Pant Samrat are also promising against these two pests. Of these varieties, only Pant Samrat is a recommended variety and 'Kharua Bengena' is a locally grown popular variety of Assam. The other two promising varieties may also be considered for recommendation after assessing their suitability under various agro-climatic conditions of Assam.

CHAPTER VI

SUMMARY

Studies on the population ecology and varietal preference of *Aphis gossypii* Glover. and *Henosepilachna vigintioctopunctata* (Fab.) on brinjal were conducted at Assam Agricultural University, Jorhat during 1998-99 and 1999-2000.

The results obtained from the studies are summarized below:

The infestation of *A. gossypii* on brinjal commenced at the seedling (S₁) stage of the crop during the second week of October in 1998-99 and second week of November in 1999-2000. The population of apterous nymphs and adults increased steadily from the late vegetative stage of the crop and reached their peak at the flowering stage of the crop during the last week of January in 1998-99 and last week of February in 1999-2000. After attaining peak, the population showed a declining trend till the last stage of the crop during the month of April, when the alate adult populations reached peak densities. Seasonal mean population densities calculated were 5.15 and 1.50 aphids per 6 leaves in 1998-99 and 1999-2000, respectively.

Three coccinellid predators were recorded as a potential biocontrol agents of *A. gossypii*, viz., *Coccinella repanda* Thunb., *Menochilus sexmaculatus* F. and *Micraspis discolor* (F.). The population of these coccinellids showed significant positive association with the population of apterous aphids.

In laboratory tests, *C. repanda* was found to be a highly efficient predator, consuming a maximum of 29.90 *A. gossypii* in 24 hours.

Bright sunshine hours exhibited significant positive correlation (pooled) with nymphal and overall aphid populations (nymph + adult) of *A. gossypii* ($r = 0.414$, $P = 0.05$ and $r = 0.399$, $P = 0.05$, respectively). Other meteorological factors had non-significant correlation with their population.

H. vigintioctopunctata first appeared in the brinjal field during the second week of October in 1998-99 and fourth week of November in 1999-2000, when the crop was in seedling (S_3) stage. The peak incidence of the beetle could be noticed during the first week of March in the first year crop and during the fourth week of March, in the second year crop, when the crop attained R_4 and R_5 stage (fruit maturation and ripening). Soon after attaining peak, the population declined to almost traceless within three to four weeks during the last stages (R_4 and R_7) of the crop in the month of April. Seasonal mean populations harboured by the crop were 1.82 beetles/2 branches and 0.67 beetles/2 branches in 1998-99 and 1999-2000, respectively.

H. vigintioctopunctata was parasitized by two hymenopteran parasitoids of the family Eulophidae. Of these, *Tetrastichus* sp. was found to parasitize eggs and early instar larvae, while the *Pediobius foveolatus* Craw. parasitized mainly pupae but also found to parasitize late instar larvae. There were significant positive correlation between host population and extent of parasitization by both the parasitoids.

Morning relative humidity was found to have significant negative effect on larval ($r = -0.460$, $P = 0.05$), pupal ($r = -0.485$, $P = 0.01$), adult ($r = -0.537$, $P = 0.01$) and

overall population (larva + pupa + adult) ($r = -0.530$, $P = 0.01$) of *H. vigintioctopunctata*. All other meteorological factors had no significant association with the beetle population.

Spatial distribution pattern of *A. gossypii* nymphs and adults of apterous form, and alate adults on brinjal crop were contagious. However, distribution showed regularity in one or two initial sample dates in case of adults in both the years of study and nymphs in the first year. Distribution pattern of immature and adult stages of *H. vigintioctopunctata* were also contagious in both the years, except in few initial and later phases of crop growth, where distribution was regular. However, adults in the first year also showed regularity in distribution during flowering stage of the crop. Mean clump sizes for *A. gossypii* nymphs and adults, an immature stages and adults of *H. vigintioctopunctata* indicated that aggregations in most of the cases for both the insects were due to environmental heterogeneity in the crop field and due to active behaviour of the pest.

The clumped distribution of *A. gossypii* nymphs and adults as well as immature and adults of *H. vigintioctopunctata* were further confirmed by Iwao's patchiness regression and Taylor's power law models. Both the models gave good fitness to the population distribution of these two pests.

Optimum sample numbers estimated (Ruesink, 1980) for both the sampling methods at two levels of precision (10 and 25%) showed that the required sample numbers were more or less same in the case of *A. gossypii*, whereas slight variation occurred in the case of *H. vigintioctopunctata*. The optimum plant numbers (average of two years data) required for ecological studies (10% precision level) of *A. gossypii* were 91 and 77 for nymphs and, 105 and 89 for adults under PI(A)-1 and PI(A)-2 sampling methods, respectively. While for pest management studies (25 % precision level) it

numbered 14 and 12 for nymphs and, 17 and 14 for adults for egg clusters, larvae, pupae and adults of *H. vigintioctopunctata*, the optimum number of samples in PI(L)-1 and PI(L)-2 for ecological studies were 196 and 172, 196 and 131, 216 and 143, and 285 and 196, respectively. Whereas, the reasonable samples for pest management studies would be 35 and 29 for egg clusters, 37 and 21 for larvae, 35 and 24 for pupae, and 47 and 32 for adults under the sampling methods, respectively.

Brinjal varieties differed significantly in respect of intensity of attack and population density of *A. gossypii* and *H. vigintioctopunctata*. Based on population density of *A. gossypii*, the varieties Aruna and 'Kharua Bengena' were ranked as resistant. Moderately resistant varieties were Pant Samrat, KS-331 and Pusa Bindu. Varieties Arka Nidhi, Pusa Kranti, AB-2, Arka Keshav and Pusa Bhairav were moderately susceptible, while the susceptible varieties were Neelam Long, Pusa Uttam, 'Sagalisingia', Muktakeshi, Pusa Purple Long and JC-2. Based on population density of *H. vigintioctopunctata*, the variety, 'Kharua Bengena' was again found to be resistant followed by varieties Aruna, KS-331, Pant Samrat, 'Sagalisingia', Muktakeshi and Pusa Kranti, which were found to be moderately resistant. Moderately susceptible varieties were AB-2, Arka Keshav, Arka Nidhi and Neelam Long, while Pusa Bhairav, JC-2, Pusa Uttam, Pusa Bindu and Pusa Purple Long were susceptible varieties.

Among the life parameters of *A. gossypii*, only the total nymphal period and rate of nymphal deposition were significantly affected by the varieties. Resistant varieties, Aruna and 'Kharua Bengena' delayed nymphal development (8.09 – 8.31 days) and reduced the rate of nymphal deposition (3.18 – 3.30 nymphs/female/day) of *A. gossypii*. As regards *H. vigintioctopunctata*, the only resistant variety, 'Kharua Bengena' markedly

affected each and every life parameters except oviposition period. The resistant variety accounted for longer incubation period (4.46 days), total larval period (21.49 days), pupal period (5.48 days), pre-oviposition period (13.44 days), lowest fecundity (102.30 eggs per female) and reproductive rate (5.16 eggs/female/day), shorter adult longevity (41.80 days) and higher male:female ratio (2.33:1). Hatchability (56%), larval survival (53.30%), adult emergence (71.40%) and growth index (2.48) were also significantly lowered by the resistant varieties.

The possible cause of differential varietal response of brinjal crop to the attack of *A. gossypii* and *H. vigintioctopunctata* were established. None of the physical varietal characters studied showed association with resistance against *A. gossypii*. However, leaf area of young ($r = 0.551$, $P = 0.05$) and medium aged ($r = 0.532$, $P = 0.05$) leaf showed positive correlation with the rate of oviposition of *H. vigintioctopunctata*. Red colour intensity of leaves of brinjal varieties also had significant correlation with larval period ($r = -0.565$, $P = 0.05$), adult longevity ($r = 0.640$, $P = 0.01$), fecundity ($r = 0.556$, $P = 0.05$) and rate of oviposition ($r = 0.511$, $P = 0.05$) of this phytophagous coccinellid. Of the biochemical contents of brinjal varieties, potassium ($r = -0.546$, $P = 0.05$) and moisture contents ($r = -0.497$, $P = 0.05$) of brinjal leaves had negative significant association and total carbohydrate content ($r = 0.543$, $P = 0.05$) had positive significant association with the population density of *A. gossypii* in the field. Whereas tannin content and total phenol content of brinjal variety leaves were significantly correlated with population density ($r = -0.550$, $P = 0.05$ and $r = 0.691$, $P = 0.01$), rate of oviposition ($r = -0.498$, $P = 0.05$ and $r = -0.621$, $P = 0.01$) and sex ratio ($r = 0.503$, $P = 0.05$) and ($r = 0.654$, $P = 0.01$) of *H. vigintioctopunctata*, respectively. Total phenol content also had significant negative

association with fecundity ($r = - 0.592$, $P = 0.05$) of the beetle. Finally, it could be inferred that varieties with higher potassium content, higher moisture content and lower level of total carbohydrate content in leaves were resistant to *A. gossypii*, while varieties with smaller leaf area, higher red colour intensity, higher tannin content and higher total phenol content in leaves were resistant to *H. vigintioctopunctata*.

Among the 16 varieties of brinjal tested, only 'Kharua Bengena' was found to be resistant and, KS-331 and Pant Samrat were moderately resistant against both *A. gossypii* and *H. vigintioctopunctata*, while varieties Pusa Utam, Pusa Purple Long and JC-2 were found to be the susceptible ones to these pests.

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Appendices

APPENDIX I

Weekly meteorological data for the period of field experimentation at Assam Agricultural University, Jorhat during 1998-99

Date	Average temperature (°C)		Average relative humidity (%)		Total rainfall (mm)	B.S.S.H. (h.)	No. of rainy days
	Max.	Min.	Morn.	Even.			
October 8-14	34.0	25.0	90.0	75.0	0.0	8.5	0.0
15-21	30.3	23.7	94.0	85.0	78.6	3.7	6.0
22-28	29.4	23.8	94.0	79.0	12.8	4.8	1.0
October 29-November 4	29.6	20.8	95.0	77.0	0.0	5.8	0.0
5-11	29.3	17.9	94.0	73.0	0.0	8.6	0.0
12-18	27.6	16.3	95.0	72.0	0.0	8.1	0.0
19-25	28.0	18.9	95.0	73.0	42.4	4.3	4.0
November 26-December 2	28.5	16.9	96.0	68.0	0.0	7.9	0.0
3-9	27.5	14.3	96.0	66.0	0.0	9.2	0.0
10-16	25.8	12.4	96.0	71.0	0.0	8.0	0.0
17-23	24.5	10.3	98.0	63.0	0.0	7.4	0.0
24-31	24.5	9.1	97.0	63.0	0.0	8.3	0.0
January 1-7	24.3	8.5	97.0	65.0	0.0	8.0	0.0
8-14	22.7	7.9	97.0	71.0	0.5	7.0	1.0
15-21	24.4	8.0	96.0	59.0	0.0	8.7	0.0
22-28	25.5	9.8	95.0	61.0	0.0	9.4	0.0
January 29-February 4	25.7	11.0	95.0	70.0	3.7	8.3	1.0
5-11	28.5	12.5	93.0	63.0	0.0	7.8	0.0
12-18	30.1	13.7	91.0	64.0	0.0	8.7	0.0
19-25	29.0	15.1	92.0	66.0	0.0	7.7	0.0
February 26-March 4	30.2	15.5	91.0	63.0	0.0	8.4	0.0
5-11	30.5	16.2	91.0	62.0	0.0	7.0	0.0
12-18	30.1	16.4	91.0	66.0	0.0	6.1	0.0
19-25	31.1	16.1	92.0	62.0	0.0	6.1	0.0
March 26 -April 1	28.7	17.9	92.0	70.0	42.0	5.0	3.0
2-8	28.5	19.1	93.0	67.0	29.3	6.0	4.0
9-15	30.7	20.2	91.0	66.0	12.1	6.2	2.0
16-22	32.5	22.0	90.0	59.0	0.0	7.7	0.0

APPENDIX II

**Weekly meteorological data for the period of field experimentation at Assam
Agricultural University, Jorhat during 1999-2000**

Date	Average temperature (°C)		Average relative humidity (%)		Total rainfall (mm)	B.S.S.H. (h.)	No. of rainy days
	Max.	Min.	Morn.	Even.			
November 5-11	29.8	20.1	94.0	74.0	0.0	8.8	0.0
12-18	28.7	17.1	95.0	78.0	0.0	9.7	0.0
19-25	27.3	15.8	95.0	78.0	0.0	8.7	0.0
November 26-December 2	27.3	13.0	97.0	69.0	0.0	9.0	0.0
3-9	26.3	11.4	96.0	69.0	0.0	9.7	0.0
10-16	26.4	13.5	94.0	68.0	0.0	10.1	0.0
17-23	24.8	10.1	97.0	74.0	0.0	8.7	0.0
24-30	23.6	9.3	99.0	79.0	0.2	7.2	1.0
December 31-January 6	23.1	6.7	99.0	73.0	0.0	9.8	0.0
7-13	23.6	8.7	97.0	69.0	0.0	9.0	0.0
14-20	21.8	9.6	98.0	76.0	0.0	6.2	0.0
21-27	21.0	11.6	94.0	83.0	12.5	4.3	3.0
January 28-February 3	22.7	10.4	95.0	76.0	8.6	7.3	2.0
4-10	22.9	10.9	92.0	69.0	0.0	7.0	0.0
11-18	25.3	10.6	90.0	59.0	0.0	9.0	0.0
19-24	24.7	16.5	90.0	63.0	0.0	8.5	0.0
February 25-March 2	23.9	11.2	92.0	73.0	10.8	6.0	3.0
3-9	23.9	13.7	89.0	71.0	1.1	6.1	3.0
10-17	21.8	13.8	91.0	75.0	11.9	2.9	5.0
18-24	27.5	14.6	89.0	64.0	0.0	8.4	0.0
25-31	30.7	16.0	89.0	65.0	0.5	5.7	1.0
April 1-7	27.8	17.6	91.0	75.0	8.5	5.3	4.0
8-14	29.5	17.3	92.0	71.0	43.7	7.4	5.0
15-21	31.5	16.9	89.0	65.0	26.1	5.8	3.0

APPENDIX III
Laboratory meteorological data during the study period
(18 January to 24 April, 1999)

Date	Temperature (°C)		Average relative humidity (%)
	Maximum	Minimum	
January, 1999			
18	17.60	9.8	73.00
19	17.50	10.2	76.00
20	17.80	9.9	74.00
21	18.00	10.3	72.00
22	18.10	10.00	70.00
23	17.90	10.10	71.00
24	18.30	10.30	72.00
25	19.00	11.20	74.00
26	18.80	11.00	76.00
27	19.20	11.00	75.00
28	19.10	11.10	74.50
29	19.50	11.30	76.00
30	19.70	11.40	79.00
31	19.20	11.30	81.00
February, 1999			
1	19.80	11.50	80.00
2	20.00	11.80	78.50
3	21.10	12.10	79.00
4	20.20	12.30	78.00
5	22.10	12.60	77.00
6	21.40	12.80	79.00
7	20.80	13.20	76.00
8	21.50	13.90	77.00
9	23.30	14.40	75.50

Date	Temperature ($^{\circ}\text{C}$)		Average relative humidity (%)
	Maximum	Minimum	
February, 1999			
10	22.20	14.20	74.00
11	22.50	14.10	78.00
12	22.80	14.30	76.00
13	23.40	14.10	75.00
14	24.00	13.80	73.00
15	23.40	14.20	71.00
16	24.00	13.40	77.00
17	23.20	15.10	76.00
18	22.10	15.30	79.00
19	21.00	15.60	74.00
20	23.00	15.10	73.50
21	22.30	15.80	75.00
22	23.50	15.30	74.00
23	23.30	15.40	72.00
24	24.50	15.60	75.00
25	22.60	15.20	76.00
26	23.30	15.60	73.50
27	24.00	15.80	74.00
28	23.00	15.30	71.00
March, 1999			
1	22.80	15.40	73.00
2	23.50	15.80	72.00
3	24.20	16.10	76.00
4	24.30	16.30	77.00
5	23.50	16.00	78.50
6	24.20	16.30	74.00
7	23.90	15.90	76.00

Date	Temperature ($^{\circ}\text{C}$)		Average relative humidity (%)
	Maximum	Minimum	
March, 1999			
8	25.10	16.30	80.00
9	24.80	16.60	73.00
10	23.30	16.40	79.00
11	24.60	16.10	80.00
12	24.30	16.80	84.00
13	26.20	16.70	79.00
14	25.10	16.30	77.50
15	24.10	16.00	80.00
16	26.00	16.90	76.00
17	24.80	16.50	79.00
18	25.20	16.80	74.00
19	24.80	16.00	76.50
20	26.20	16.30	78.00
21	25.50	15.90	78.00
22	26.20	16.60	79.00
23	24.70	16.10	80.00
24	25.40	16.30	74.00
25	26.20	16.40	78.00
26	20.40	17.30	85.00
27	19.60	17.10	86.00
28	21.40	17.60	87.00
29	21.20	17.50	84.00
30	22.30	17.90	82.00
31	21.50	17.60	80.50
April, 1999			
1	21.30	18.00	80.00

Date	Temperature (°C)		Average relative humidity (%)
	Maximum	Minimum	
April, 1999			
2	20.80	18.20	83.50
3	20.40	18.10	84.00
4	22.50	18.40	81.00
5	21.60	18.20	82.00
6	22.80	18.30	84.00
7	20.40	17.60	88.00
8	22.90	18.50	83.00
9	23.30	18.20	80.00
10	22.60	18.00	82.50
11	23.50	18.50	81.00
12	23.80	19.30	86.00
13	24.00	19.50	81.50
14	25.00	20.50	74.50
15	26.50	21.50	77.50
16	25.00	21.00	78.00
17	24.50	20.00	76.00
18	24.00	21.00	75.50
19	25.00	21.50	74.00
20	26.00	21.50	79.00
21	23.50	20.00	75.50
22	24.60	22.40	78.00
23	23.50	20.20	83.50
24	25.00	22.30	80.00

APPENDIX IV

Description of growth stages of brinjal plant (var. Pusa Purple Long)

Stage code	Stage title	Description
Seedling stage		
S ₁	Young seedling	First 3-leaf stage
S ₂	Medium aged seedling	Leaf formation on main stem
S ₃	Old seedling	5-leaf stage
Vegetative stage		
V ₁	Early vegetative	Main stem with 1 branch containing 4-5 leaves
V ₂	Mid vegetative	Main stem with 2-5 branches containing 15-30 leaves
V ₃	Late vegetative	Main stem with more than 5 branches containing approximately 50-60 leaves
Reproductive stage		
R ₁	Flower bud formation	1 or 2 clusters of flower buds at any internode
R ₂	Flowering	1 or 2 open flowers at any internodes with 4-5 clusters of flower buds
R ₃	Fruit initiation	Initiation of 1 or 2 fruits with 4-5 open flowers
R ₄	Fruit maturation	1 or 2 matured fruits with 6-8 open flowers
R ₅	Fruit ripening	1 or 2 ripened fruits with 1-2 matured fruits and 2-4 open flowers
R ₆	Fruit ripening and leaf falling	50% of fruits ripened and leaf begins to fall
R ₇	Fructing cessation and leaf falling	90% fruits ripened, no fructing and more than 30% leaf fall

APPENDIX V

Source of seed material and status of brinjal varieties used in the study

Variety	Source	Yield (q/ha)	Status
Pusa Kranti	Div. of Vegetable crops, I.A.R.I., New Delhi-12	185-200	*Recommended
Pusa Purple Long	-do-	200-230	-do-
Pusa Bindu	-do-	200-220	**Promising
Pusa Uttam	-do-	185-195	-do-
Pusa Bhairav	-do-	200-210	Recommended
AB-2	-do-	170-190	Promising
Aruna	-do-	185-200	-do-
KS-331	-do-	180-200	-do-
Pant Samrat	-do-	195-210	Recommended
Arka Keshav	Indian Institute of Horticultural Research, Hessaraghatta, Bangalore-89	190-200	Promising
Arka Nidhi	-do-	190-200	-do-
Muktakeshi	Sutton & Sons (India) Pvt. Ltd., 13D, Russell Street, Calcutta-71	180-200	-do-
Neelam Long	-do-	200-215	-do-
JC-2	AAU, Jorhat	200-230	Recommended
'Kharua Bengena' (local)	Local collection	190-210	Promising
'Sagafisingia' (local)	-do-	200-215	-do-

* Recommended for general cultivation in Assam

**Promising in varietal trials conducted in various research centres in India under AICRP schemes