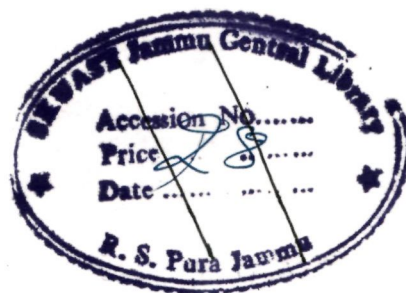


MANAGEMENT OF TOMATO FRUIT BORER,
Helicoverpa armigera (HUB.)

TEJ BAHADUR SINGH



DIVISION OF ENTOMOLOGY

FACULTY OF POST-GRADUATE STUDIES

THESIS

SUBMITTED TO THE FACULTY OF POST-GRADUATE STUDIES,
SHER-E-KASHMIR UNIVERSITY OF AGRICULTURAL SCIENCES
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IN PARTIAL FULFILMENT OF REQUIREMENTS
FOR THE AWARD OF THE DEGREE OF
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**SHER-E-KASHMIR
UNIVERSITY OF AGRICULTURAL SCIENCES AND TECHNOLOGY
JAMMU
2000**

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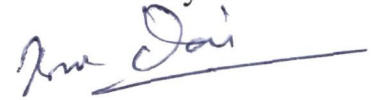


*Dedicated to
my parents*

CERTIFICATE

Certified that the corrections/ suggestions recommended by the external examiner Dr. R.D. Gautam, Senior Scientist, Department of Entomology, IARI, New Delhi have been incorporated in the thesis entitled, " Management of tomato fruit borer, *Helicoverpa armigera* (Hub.)" submitted by Tej Bahadur Singh, Regd. No. 98/A/490/M in partial fulfillment of the requirements for the degree of **Master of Science in Agriculture** (Entomology).

Chairman Advisory Committee




(S. Kirpal Singh)



Certificate - I

This is to certify that the thesis entitled “**Management of tomato fruit borer, *Helicoverpa armigera*(Hub.)**” submitted in partial fulfilment of **Master of Science in Agriculture(Entomology)** to the **Faculty of Post Graduate Studies, Sher-e-Kashmir University of Agricultural Sciences and Technology, Jammu**, is a record of bonafide research carried out by **S.Tej Bahadur Singh**, under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

It is further certified that such helps or information received during the course of investigation have been duly acknowledged.


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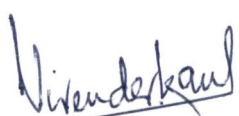
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We, the members of advisory committee of **S. Tej Bahadur Singh**, a candidate for the degree of **Master of Science in Agriculture(Entomology)**, have gone through the manuscript of the thesis entitled "**Management of tomato fruit borer, *H. armigera*(Hub.)**" and recommend that it may be submitted by the student in partial fulfilment of the requirements for the degree.



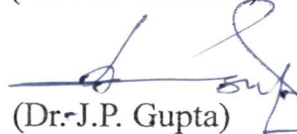
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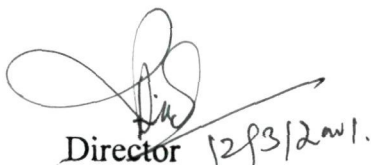
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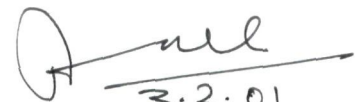
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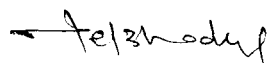
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ABSTRACT

The experiment was conducted during 1999 at Vegetable Research Sub station Ponichak, Jammu. Seven insecticides namely, endosulfan 35EC, malathion 50EC, carbaryl 50WP, fenvalerate 20EC, cypermethrin 25EC, decamethrin 2.8EC and dichlorvos 76EC were evaluated against tomato fruit borer. All the treatments were found significantly superior to control. However, decamethrin 0.0025 per cent proved most effective in reducing the infestation whereas, dichlorvos 0.05 per cent was least effective. During the present investigations on pest - tomato interaction, a few parasitoids were found associated with this pest. *Campoletis chloridae* Uchida and *Chelonus blackburni* Cameron were found parasitising the tomato fruit borer. Study reveals that *C. chloridae* made its presence throughout the cropping season while *C. blackburni* was active during the peak period of the crop. Though, the highest fruit yield(130.96 q/ha) was obtained from the plots treated with decamethrin, yet highest cost benefit ratio 1:24.73 was obtained from the plots treated with malathion and decamethrin(1:19.44), respectively.

INTRODUCTION

1. INTRODUCTION

Tomato, *Lycopersicon esculentum*, Milliere is of tropical American origin and belongs to family solanaceae. It is known for its high nutritive value, being a good source of vitamin A and B and an excellent source of vitamin C (Katyal, 1985). It is very popular and grown all over the world, both as out door and under glass, for fresh consumption and processing. In India it was introduced in the late 19th century and its cultivation spread rapidly making it one of the most popular crops, being grown over an area of 31000 hectares with an annual production of 4600 thousand metric tonnes of fruits (Anon., 1993). In Jammu province of Jammu and Kashmir state, tomato is grown throughout the year over an area of 1200 hectares with an annual production of 26, 400 tonnes (Anon., 1997).

Like other vegetable crops, tomato supports a complex of pests, including nematodes, pathogens, weeds, insects and other arthropods. All parts of the plant offer food, shelter and reproduction site for insects. Worldwide more than a hundred different pest species have been reported on tomato crop (Berlinger, 1986) which affect it, both quantitatively and qualitatively.

In India the average yield of tomato is 14.8 tonnes per hectare against the world average of 25.93 tonnes (Anon., 1993). One of the most important reason is that tomato agroecosystem is attacked by a few major key pests and many minor pests, such as borers, cutworms, aphids, jassids, green bugs, leaf bugs, thrips, white

flies and leaf hoppers (Atwal and Dhaliwal, 1997b). Among these, the tomato fruit borer, *Helicoverpa armigera* (Hubner) is the serious one (Kashyap and Verma, 1986; Singh and Narang, 1990).

It is cosmopolitan in distribution and is found in all the countries of the world - Africa, the Middle East, Southern Europe, India, Central and South-East Asia, Eastern and Northern Australia, New Zealand and many Eastern-pacific Islands (Gary, 1989). It is polyphagous insect pest causing serious damage to 181 cultivated and wild plant species (Manjunath *et. al.*, 1985). Besides tomato, it has also assumed alarming proportions on cotton (Sidhu *et. al.*, 1991).

The larva of tomato fruit-borer not only infests tomato fruits but also flower buds and flowers (Lal and Lal, 1996) which results in a huge unpredictable loss in terms of yield by preventing the formation of fruits. Its habit of damaging several fruits without completely devouring the first infested fruit enables it to destroy 2-8 fruits in its life time (Butani and Jotwani, 1984). Therefore, the damage due to tomato fruit borer is severe on tomato and is reported to cause 50-100 per cent loss under natural conditions (Singh and Narang, 1990). However, no such records are documented under local Jammu conditions.

Various workers advocated management of tomato fruit-borer using insecticides due to their instant action. Different groups of insecticides like organochlorines, organophosphates, carbamates and synthetic pyrethroids have been successfully evaluated and recommended at different stages of tomato crop against the *H. armigera*.

To accomplish the present investigations under Jammu agro-climatic conditions for the tomato crop, it was felt necessary to study the fruit-borer under the

following objectives:

1. Evaluation of insecticides for the management of tomato fruit-borer, *H.armigera* on tomato (*L. esculentum*).
2. Collection, preservation and identification of larval parasites of tomatofruit borer.
3. Computation of cost benefit ratio of the insecticides used.

REVIEW OF
LITERATURE

2. REVIEW OF LITERATURE

Pest management is a complex technology of maintaining pest populations at low levels through ecological manipulations in an environmental friendly and economical way. It involves the exploitation of pest biology vis - a - vis the climate and judicious use of pest management measures. The present chapter deals with the review of available literature on management of tomato fruit-borer, *H.armigera* (Hubner). Efforts have been made to collect the available information on the relevant aspects related to the aforesaid subject under the following heads :

2.1 Evaluation of insecticides for the management of tomato fruit-borer, *H.armigera* on tomato (*L. esculentum*).

Reports of Srinivasan (1959) revealed that the use of 0.1 percent DDT or 0.02 percent aldrin was more effective in controlling the tomato fruit- borer than application of 0.025 percent parathion, whereas, Russo and Tremola (1961) reported that 0.02 per cent dimethoate and parathion at 0.03 per cent were effective against the tomato fruit-borer.

Laboratory studies on the comparative efficacy of various insecticides conducted by Chanthani and Adkinsson (1966) revealed that phosphatic insecticides were more toxic than endrin to eggs and adults. However, endrin was more toxic to

the larvae. In another study Gaikward (1969) reported carbaryl at 0.02 per cent effective against tomato fruit-borer.

Singh and Singh (1970) conducted study on the efficacy of nine insecticides viz., diazinon (0.2 L/ha), endosulfan and fenitrothion (0.4 L/ha), gardona (0.6 Kg/ha), malathion (0.6 Kg/ha), carbaryl + DDT (0.8 Kg/ha), DDT + endosulfan (2.0 L/ha) and methyl parathion and DDT (4.0 L/ha) tomato fruit-borer. They concluded that five promising insecticides in the order of efficacy were carbaryl > gardona > DDT + endosulfan > methyl parathion + DDT > endosulfan. Trichlorfan 0.25 per cent also was reported effective in controlling fruit-borer (Gomez, 1972).

From the two field experiments with 12 insecticides, it was observed that 0.05 percent quinalphos was the most promising insecticide. The treatment with 0.05 percent fenitrothion, 0.05 per cent monocrotophos and 0.2 per cent carbaryl were at par with 0.05 percent quinalphos during 1971, whileas 0.05 per cent monocrotophos, 0.05 percent fenitrothion, 0.1 per cent dicrotophos and 0.2 per cent phosphamidon were found to be equally effective during 1972. From the results it was concluded that 0.05 percent quinalphos or 0.05 per cent fenitrothion or 0.2 percent carbaryl or 0.05 per cent monocrotophos can be recommended for the control of tomato-fruit-borer (Mote and Pokharkar, 1975).

In South Africa cypermethrin (200 g a.i./ha) was compared with endosulfan (525g a.i./ha) for the control of *H. armigera* in a trial involving eleven sprays. Improved control was obtained with pyrethroids. Larval counts over the assessment period were 35 percent lower for *H.armigera* than in endosulfan treated plots. Cypermethrin in particular gave good results at low dosages against many insect species (Breese, 1977).

Butani (1977) suggested that in case of severe infestation of tomato fruits, dusting of 5 percent carbaryl or spraying with 0.2 per cent lindane or 0.04 per cent monocrotophos or 0.05 percent endosulfan was effective in reducing borer damage.

Elliott *et. al.*(1978) reported pyrethroids ten times more effective in the field than most potent compounds of other three principal groups of insecticides against a wide range of lepidopterous larvae.

Singh and Chahal (1978) evaluated the efficacy of three insecticides viz., carbaryl, endosulfan and trichorfan alternately with malathion. Alternate sprays of malathion and carbaryl at ten days interval starting from leaf perforation stage gave best results against this pest. DDT 0.1 per cent was reported to be effective in controlling the tomato fruit-borer (Smith, 1978).

According to Chu *et. al.* (1980) tomato fruit borer was controlled effectively by spraying methyomyl and tamaron 0.1 per cent on tomato crop.

Dhesi and Nandpuri(1986) suggested that tomato fruit borer can be controlled by spraying 400 ml.of malathion 50 EC in 250 liters of water before fruit setting. They also recommended use of 350 ml of thiodon 35 EC (endosulfan) and 500gm sevin 50 WP (carbaryl) alternately at two weeks interval thereafter.

According to Bose and Som(1990) spraying of 0.05 per cent endosulfan gave a good control of tomato fruit borer. They recommended 1.5 ml of thiodan 35 EC to be mixed in one litre of water at the rate of 800 litres per hectare.

Field experiments carried out by singh and Narang (1990) for the control of tomato fruit borer with synthetic pyrethroid group of insecticides (fenvalerate, permethrin, cypermethrin and decamethrin) at different doses and results were

compared with standard insecticides (carbaryl and endosulfan) and the untreated plots. Application at the rate of 50g a.i. per hectare of either of the insecticides or 20g a.i per hectare of decamethrin at two weeks interval starting from the initiation of flowers, gave better protection of the crop from the borer compared to carbaryl or endosulfan at high dose of 1000 and 700g a.i per hectare, respectively. It also resulted in higher fruit yield and net returns.

Sharma *et. al.* (1992) reported that two sprays of cypermethrin (10 EC) permethrin (50 EC), deltamethrin (2.8 EC), fenvalerate (20EC) and carbaryl (50WP) were applied at an interval of 10, 15 and 20 days against the pod-borer. Deltamethrin with 15 days interval between the sprays was the most effective treatment.

Khan *et. al.* (1993) while evaluating the effect of endosulfan (thiodon 35 Ec) cyfluthrin, methamidophos and fluvalinate against *H. armigera* found that endosulfan and cyfluthrin were more effective than methamidophos and fluvalinate against the pest.

Sharma *et. al.* (1993) evaluated various insecticides viz., fenitrothion, fenthion, phosalone, quinalphos, chlorpyrifos, malathion, cypermethrin, fenvalerate and decamethrin against tomato fruit borer and reported that synthetic pyrethroids proved better than organophosphates and organochlorines. The yield was higher in case of decamethrin, fenvalerate and cypermethrin treated plots.

Noorani *et. al.* (1994) observed that after two applications of endosulfan, cyfluthrin and cyhalothrin, larval population of *H. armigera* per plant averaged 0.88, 1.96 and 2.78 compared to 26.72 in control.

Abrol and Bhat (1996) while conducting experiments on the effect of different spacings, intercropping and insecticides against tomato fruit borer, concluded that spacing and inter cropping had no significant effect on the fruit infestation by the

pest. However, all the insecticides tested were reported to be very effective in controlling tomato fruit borer. Spraying of quinalphos, cypermethrin, monocrotophos and phosmit at the rate of 1.0, 1.5., 2.0. and 1.5 ml per litre of water, respectively gave 3.06, 4.29, 2.28 and 1.76 per cent fruit infestation compared to 17.78 per cent in the control plots.

Atwal and Dhaliwal (1997a) suggested that fruit borer was controlled by spraying at fruit initiation stage. They recommended 2.5 litres of endosulfan 35 EC or 250 ml. of fenvalerate 20 EC or 200 ml of cypermethrin 25 EC or 400 ml. of deltamethrin 25 EC in 625 litres of water per hectare at the start of fruit formation and repetition after two weeks, if necessary. They further recommended alternate use of fenvalerate 0.4 per cent dust at the rate of 20 kg per hectare or malathion 5 per cent dust at the rate of 25 kg per hectare or endosulfan 2 percent dust at the rate of 25 kg per hectare for effective control of tomato fruit borer.

2.2 Collection, preservation and identification of larval parasites of tomato fruit borer.

Most of the pests which play a detrimental role in the over all agricultural productivity scenario, have their natural enemies. It has been observed that on a particular host plant when population build up of pest diminishes, the associated parasitoids/other natural enemies are found to be increased. This is a continuous process in the nature. In order to avoid excessive use of chemicals in controlling the pests, these parasitoids, if manipulated may prove to be a potential source for suppressing the pest population without contaminating the environment. This necessitates a thorough overview of possible natural enemies of tomato fruit borer, *Helicoverpa armigera* (Hubner). The literature on parasitoids of tomato fruit borer is reviewed as under:

2.2.1 New records of parasitoids

Several workers have recorded natural enemies of *H. armigera*. The earliest report of parasitoids of this pest was recorded by Hussain and Mathur (1924), wherein *Microplitis* sp. (Braconidae) and *Atractodes* sp. (Ichneumonidae) found mention. Later, Ayyar (1927) recorded *Tetrastichus ayyari* Rohwer as a new parasite. Other records in India include *Chelonus* sp. (Chopra, 1928); *Apanteles ruficrus*, Hal. and Bracon (*Microbracon brevicornis* Wesm. (Winsburn and Painter, 1932); *Chelonus narayani* Suba Rao (Suba Rao, 1955); *Horogenes fenestralis* (Hlmgr.) (Tikar and Thakare, 1961); *Campoletis perdistinctus*, Viereck (Gangrade, 1964) and *Banchopsis ruficornis*, Cameroon (Mathur, 1967).

Manjunath *et. al.* (1970) recorded *Trichogramma australicum* G. and *T. achaeae* (egg parasitoids) from India. Mathur (1970) mentioned four new parasites viz., *Euplectrus* sp. (External, gregarious, larval parasites), *Netelia* sp. (External, solitary, larval parasites), *Palexorista* sp. (internal, solitary, larval parasite) and *Agrypon nox* Morl. (internal, solitary, larval parasite). The other records were : *Carcelia illota* Curran, *Goniophthalamus halli* (Mesnil), *Campoletis flavicinicta* (Ashm.) and *Ecphoropsis perdistinctus* (Vier.) (Patel *et. al.*, 1971); *Brachymeria lasus* (walker) (Joseph *et al.* 1973); *Enicospillis biconatus* T. and *Palezorista* sp., two larval parasites (Bilapate, 1981) and *Eucarcelia* sp. (Sithanantham, 1981). Divakar and Pawar (1987) reported *Parasieta* sp. as a new record from Karnatka. Singh and Balan (1986) reported the braconids *Apanteles* sp., *Bracon* sp. and *Microbracon hebetora*, the Ichneumonids *Campoletis chloridae* and Eulophid - *Euplectrus euplexa*, all larval parasitoids. *Hockeria apani* Doganlar was recorded from Turkey (Doganlar, 1990)

2.2.2 Indigenous parasitoids (India)

Helicoverpa armigera larva is reported to be parasitized by as many as 85 species of parasitoids (Rao, 1968), whereas more than 70 parasitoids and predators have been recorded attacking *H. armigera* in India (Shekhon, 1980). Tikar and Thakare (1961) stated that *Nyctobia fenestralis* Halmgr. was exerting considerable control of *H. armigera*, infesting gram in Maharashtra State. They further reported that parasitization decreased gradually in February-March owing to high temperature and hyperparasitization at Nagpur. According to Gangrade (1964), the parasitization by *Campoletis perdistinctus* was to the extent of 34.5 per cent in Madhya Pradesh. A detailed account of the parasites of *H. armigera* in India were enlisted by Achan *et al.* (1968) and reported 80 per cent parasitism due to *Ecphoropsis perdistinctus* (Hym.: Eulophidae). Manjunath *et al.* (1970) reared two egg parasitoids- *T. australium* Girault and *T. achae* Nagaraja and Nagarkatti and a Scelionid *Telenomus* sp. and inferred that parasitism by *Trichogramma* spp. ranged from 20-80 per cent. Rao (1968) observed that *Banchopsis ruficornis* (Cam.) (Solitary, Larval parasite) caused 10 per cent parasitism in the field. Under the agro climatic conditions of Gujrat, the parasitization by *Carcelia illota* Curran, *Ecphoropsis perdistinctus* Vier. and *Goniophthalamus halli* Mesnil was reported by Patel *et al.* (1971).

Field parasitization by egg parasites *Trichogramma* spp. were found to be high, 80 percent on tomatoes and cow peas, whereas the level of parasitism was very poor in the crop of chickpea due to glandular hair on the leaves which produced acidic exudates and trapped the adult parasitoids (Bhatnagar and Davies, 1978). Later on, Bhatnagar (1981) also seconded the findings by recording the high degree of mortality to eggs and larvae of *H. armigera* by *Trichogramma* spp. The percent parasitization of *Apanteles* sp. and *Bracon hebetor* was reported to be 85 and 11 per cent, respectively (Singh *et al.* 1983). The extent of parasitization by these parasitoids reached

to maximum in the months of January (in case of early sown crops) and in February (in case of late sown crops) (Deka *et. al.*, 1987).

Parasitism due to *Eriborus* sp. was 43.7 percent in chickpea, 38.9 per cent by *Carcelia illota* Curran in lablab crop and *Apanteles ruficrus* (H.), *A. glomeratus* (L.), *Bracon brevicornis* (Wism), *B. greeni* (Ashm.) and *Microplitis* sp. were reported to be not effective because of level of infestation which was as low as 5 per cent (Srinivas, 1987). Further the author found that the parasitoids *P. laxa*, *Eriborus* sp. and *Bracon* sp. active on *H. armigera* in tomato and pigeon pea. Highest parasitism by *Eriborus argenteopilosus* (Cameron) was also confirmed by Bilapte *et. al.* (1988). Several parasitoids of Sorghum crop pests were observed by Pawar *et al.* (1989), viz, Hymenoptera: *Trichogramma chilonis* Ishii, *Trichogrammatoidea bactrae*, *T. fumata* Nagaraja (egg parasitoids), *Apanteles* sp, *Campoletis chloridae* Uchida, *Disophrys* sp, *Eriborus argenteopilosus* Cameron, *Eriborus trochanteratus* Morley, *Tenellucha* sp. (Larval parasites) and Diptera: *Carcelia illota* Curran, *Exorista xanthaspis* Wied., *Goniophthalamus halli* Mes., *Palexorista laxa* Curran and *Sturmiopsis inferens*. The sixteen species of natural enemies belonging to the trichogrammitidae, braconidae and ichneumonidae were recorded by Srinivas and Jayaraj (1989). They observed that *Diadegma fenestralis* collected from first to third instar larvae (10.53 to 22.39 per cent parasitization) and *Banchopsis ruficornis* from 4th to 5th instar larvae (0.56 to 3.64 per cent parasitization) were the most common parasitoids.

Sithanatham (1982) reported that natural parasitism on *H. armigera* by *T. chilonis* was only 2-3 per cent as compared to 47.2 per cent in Maize around Hyderabad. Singh (1988) opined that for tackling the immediate problem of *H. armigera* in tomato crop, inundative release of *Trichogramma chilonis* @ 2,00,000 adults per hectare at weekly interval during egg laying period should be made.

Gupta et al (1997) reared parasitoid from *H. armigera* in mid hills of Himachal Pradesh viz, *Trichogramma australicum* Girault (= *T. chilonus* Ishii) and *T. acharea* Nagaraja and Nagarkatti-both egg parasitoids and *Campoletis chloridae* Uchida, a larval parasitoid. Ravi and Verma (1997) during their studies reported that the per cent parasitization increased with the increase in the host population and the parasitization during the early cropping stages were 1.67 per cent in timely sown crop and 5.0 per cent in late sown crop, which gradually increased and later declined due to rise in temperature.

Per cent parasitization was observed by Sivaprakasam (1997) on tomato fruit borer, *H. armigera* by larval parasitoids viz, *Campoletis chloridae* (26.8 in irrigated and 18.3 in rainfed fields), *Corcelia illota* (19.3 in rainfed and 6.2 in irrigated field), *Palexorista laxa* (50 in irrigated), *Eriborus* sp. (10.5 in rainfed field) and *Bracon* sp. (7.8 in rainfed fields).

2.2.2.1 *Campoletis chloridae* Uchida

Out of 80 parasitic natural enemies recorded in India, so far, 50 belong to the hymenopterous group. Among them *Campoletis chloridae* Uchida is the most widely distributed from the Himalayas (2100 m) to the sea levels in South India. It is a solitary parasite and attacks early larval stage. The percentage of parasitism ranged from 5-10 in the field; the larval and pupal period and adult longevity of male and female were ranging from 7-10, 5-7 and 13-15 days, respectively. The feeding activity of the larva was reduced after parasitization and after the emergence of parasite, the host larva dies (Chari *et. al.*, 1988). In the findings of Sivaprakasam (1997), the percentage of parasitism by *C. chloridae* Uchida was maximum in the first week of April (26.8 per cent) in irrigated fields and 18.3 per cent during the second week of November in case of rainfed tomatoes.

At Bangalore Mani (1980) reported that the parasitism by *C. chloridae* was

maximum (20 per cent) in tomato crop during the month of April. According to Yadav and Patel (1981) the percentage parasitism by *C. chloridae* initially occurred in the second week of September and reached to maximum during December to February. Singh *et. al.* (1983) reported 4 per cent parasitization by this parasitoid. Another finding revealed that it was highest during December, lowest during February and almost nil during March (Yadav *et. al.*, 1985). Higher parasitization was reported in December at Kanpur and from February to March in Haryana (Singh and Balan, 1986). High degree of mortality to the *H. armigera* was also reported by this parasitoid (Bilapate *et. al.*, 1988). Per cent parasitization to this pest on cotton, chickpea and many other host plants was experimented by (Singh, 1988), who observed that sometimes it exceeds 35 to 83 per cent. In Uttar Pradesh, parasitism was recorded from 3rd week of April which gradually increased and reached to the maximum in the last week of May when the host infestation was at its peak (Garg, 1989). The highest parasitization was observed from October to December in Tamil Nadu by Srinivas and Jayaraj (1989). Another study conducted by Pawar *et. al.* (1989) in Andhra Pradesh, revealed that the percentage parasitism was highest in September and lowest in May. They also recorded 10 species of hyperparasitoids from cocoons of *C. chloridae* with hyperparasitism being about 40 per cent in cereals and 10 per cent in legumes. By his finding, it could safely be presumed that this parasitoid will not be effective one because it is a host of hyperparasitoid complex, where this complex exists.

Pimbert and Srivastava (1989) conducted an experiment by sowing coriander around chickpea crop and detected that parasitism was highest in rows near coriander (6.8 and 5.3 per cent) than in those without coriander. Maximum parasitism of 43.9 percent was recorded in the first fortnight of December and lowest of 12 percent during the last week of January in Tamil Nadu by Srinivas and Jayaraj (1989). Nikam and Gaikwad (1991) studied the rate of parasitization from first instar to last instar stages in laboratory and recorded the maximum parasitism in the early

stages than in the late stages. A survey conducted during 1991-92 in Orissa by Mishra *et. al.* (1992) observed that the parasitoids were more active during December and January. However Atwal and Dhaliwal (1997a) reported that this parasitoid made its presence felt throughout the cropping season. Sivaprakasam (1997) reported maximum percentage of parasitism by *C. chloridae* in the 1st week of April (26.8 per cent) in irrigated fields and minimum (18.3 per cent) during the second week of November in case of rainfed tomatoes.

2.2.3 Introduced Parasitoids (India)

Commonwealth Institute of Biological Control imported 5 parasitoids viz., *Eucelatoric bryani* (S), *Cotesia marqiniventris* (C), *Campoletis flavicineta* (Ashm.), *Cotesia kazak* (T) and *Hyposoter didymator* (Thbs.). Out of these the tachnid- *E. bryani* preferred 4th and 5th instar stages of *H. armigera* (Mani and Nagarkatti, 1981).

Following parasitoids were introduced in India since 1969 to test them against *H. armigera* on many crops including tomato. *T. brasiliensis* (Ashm.) (South Africa), *T. perkinsi* Girault (USA), *T. pretiosum* Riley (Mexico and USA), *Chelonus blackburni* (Cameron) (Arizona), *C. insularis* (West Indies), *C. kazak* Telenga (Greece), *Campoletis flavicinica* (Ashm.) (Trinidad), *Hyposoter didymator* (Thunberg) (Greece), *Lespesia archippivora* (Riley) and *Eucelatoria bryani* Sabrosky (Arizona) (Krishnamurthy and Mani, 1988). For tackling the problem of *H. armigera* in India, a few exotic natural enemies viz., *Apanteles marqiniventris*, *Lespesia archippivora*, *C. blackburni*, *E. bryani* and *T. pretiosum* from Africa and *T. brasiliensis* from South Africa have been introduced and evaluated from time to time. Among these parasitoids *T. brasiliensis* has been recorded on tomato in Karnataka (parasitization 34.6 to 51.3 percent eggs of the pest), *B. kirkpatricki* from tomato eco-system in Karnataka and cotton eco-system in

Maharashtra and Gujrat, *C. blackburni* recorded from North India, *E. bryani* from tomato eco-system in Karnataka (parasitization upto 8% larvae). The parasite has already established in Eastern Uttar Pradesh and Hyderabad. *H. didymator*, which is an Eastern parasite in Russia, Bulgaria, Turkey, Syria, Israel, Spain, Morocco, and other countries, have been introduced in India (Singh, 1988). Seven parasitoids have been released in plains of Jammu for suppressing the populations of tissue borers, including *H. armigera* on various crops. Among these *T. brasiliensis*, *T. pretiosum* and *Chelonus blackburni* are of foreign origin (Anon. 1999)

The extent of parasitization by *C. blackburni*, an egg parasite in the cotton fields, was 37.77 percent (Sarkate *et. al.* 1978) and 37.8 percent (Rao *et al.* 1979). *Eucelatoria* sp. against *H. armigera* was introduced from USA and reared for the field releases (Sankaran and Nagarajan, 1979). Out of the few parasitoids released, *C. marqiniventris* failed to establish while *C. flavicincta* could not be colonised due to preponderance of males in the breeding programme but the field recovery of *E. bryani* indicated that it had established but produced very low levels of parasitism (up to 16 per cent) in tomato crop (Pawar *et. al.*, 1981; Mani and Krishnamurthy, 1983; Divakar and Pawar, 1987). Significant control in the field of gram in Haryana was observed by Prasad *et. al.* (1982) after releasing the egg larval parasite *C. blackburni*. Mani and Krishnamurthy (1983) observed 34.6-51.3 percent parasitization in tomato when released in the field. *Telenomus remus* Nixon, an egg parasitoid originating from New Guinea, can serve as an alternate host of *H. armigera* (Joshi *et. al.*, 1984).

Inundative releases of *T. brasiliensis* and *T. pretiosum* @ 2,50,000 adults per ha resulted in 16.67 to 62.94 percent and 20-71.43 per cent parasitism, respectively on tomato crop (Anon., 1987). No recovery was obtained following inoculative releases of *H. didymator* (Anon., 1987), *Cotesia marqiniventris* Cresson, a primary

parasite, introduced from U.S.A. attacked early instar larvae (3-5 days old) and parasitization ranged from 20-30% (Chari, 1987) ,whereas recovery of *E. bryani* was found throughout hte cropping season (Sithanantham, 1987).

2.2.4 Exotic parasitoids (other countries)

The list of natural enemies recorded from the distrubution range of *H. armigera* is quite long, 95 have been recorded in Uzbekistan, 40 in Krasnadar, 22 in Turkmenia and 32 in Azerbaijan. In Azerbaijan Republic, in 1964, *Bracon hebetor* alone parasitised 15-70 per cent of larvae (70 per cent parasitism was observed in September after the chemical spray was stopped); *Orius nigera* destroyed about 50-70 per cent eggs in Krasnadar province in 1970. *Hyposoter didymator* was the dominant parasitoid of the pest in Uzbekistan, *B. simonori* alone caused 45.8 per cent parasitization in cotton fields. In Tadjikistan, *Cotesia kazak* caused 5- 12 percent parasitism in the start of the season but in the third generation, the percentage parasitism reached 50-70. *Bracon hebetor* was mass produced and 1000 parasitoids were released when the population of the pest reached 12 caterpillars/100 cotton plants. Average effectiveness was 40-50 percent control, highest being 80 percent. The best period for releases was determined to be from June to August. In Turkmenia, *Copidosoma obscurus* was an important parasitoid of lucerne, tomato, chickpea and cotton. *Thirion qiqanteum* parasitized 26-34 percent caterpillar in cotton growing areas of Southern Kazakhstan. A combination of *Trichogramma* spp. and *B. hebetor* was used in Russia for combating the pest in North Syria, the prinicipal parasitoids were *Meteorus* sp. and *B. hebetor*. In South Africa 19 parasitods, have been recorded (Singh, 1988).

Over 50 per cent of parasitism of *H. armigera* in tomato field was observed with the release of *Habrobracon* (=Bracon) *hebetor* in Russia (Koralenkov

and Kozlova, 1981). Doganlar (1990) reported that in Turkey the rate of parasitism by *Diadegma* sp. and *Hyposoter didymator* was 19.7 and 6.2 per cent during 1988 and 1989, respectively. Of this fifth and sixth instar larvae were parasitised by *Habrobracon brevicornis* (*Bracon brevicornis*) (47.6 and 38.8 percent) and *Hockeria infraiensis*, a pupal parasitoid (33,56 and 80 per cent).

The studies, Murray and Ryhne (1994) in the green house experiments forecasted that the level of parasitism would enhance during the first spring generation of *H. armigera*. In Iran, Noori (1994) revealed that the activity of *Habrobracon hebetor* begun in early June and lasted till mid September and the rate of parasitism increased with increase in temperature. The parasitism occurred in the early sown than in late sown crops. Further Murray *et al.* (1995) investigated the rate of parasitism by *Hyposoter didymator* and *Cotesia kazak* and found that it was lowest on chickpea compared to sorghum, sunflower in Australia.

2.3 Computation of cost benefit ratio of the insecticides used.

Ujagir and Khare (1987) evaluated various insecticides against *H. armigera* and concluded that two applications of endosulfan (0.07 %) at the rate of 600 litres per hectare before pod initiation resulted in the highest cost benefit ratio of 1:19. However, when the crop was not protected against *H. armigera*, yield losses reached up to 80 per cent.

Singh and Narang (1990) conducted experiment to study the efficacy of six insecticides viz., fenvalerate, permethrin, cypermethrin, decanethrin, endosulfan and carbaryl at different doses. The yield in case of synthetic pyrethroids was 466.2-503.8 quintals per hectare as compared with 393.6 to 421.6 quintal per hectare in case of endosulfan and carbaryl. The treatment with pyrethroid gave Rs. 4205 to 5237 more net returns than the control as compared with 4057 to 4285 in case of endosulfan

and carbaryl. Cost-benefit ratio was Rs. 10.4, 17.1 and 25.1, respectively in case of fenvalerate, carbaryl and permethrin.

Sharma *et al.*(1993) evaluated fenitrothion, fenthion, phosalone, quinalphos, chlorpyrifos (each at 0.05 percent), cypermethrin and fenvalerate (at 0.006 per cent each) and decamethrin (0.002 percent) against tomato fruit borer and reported that synthetic pyrethroids proved better than organophosphates and organochlorines. The mean yield was higher with endosulfan, decamethrin, fenvalerate and cypermethrin sprays. Net gain in treated plots was maximum (Rs. 8478/ha) when crop was sprayed with decamethrin, Rs. 8278/ha and Rs. 8239/ha in case of fenvalerate and cypermethrin, respectively. Cost benefit ratio was Rs. 10.81 in case of endosulfan followed by cypermethrin (Rs. 11.77), decamethrin (Rs. 17.66) and fenvalerate (Rs. 18.19) in ascending order.

MATERIALS
AND
METHODS

3. MATERIALS AND METHODS

The present investigations were carried out during 1999 at Vegetable Research Sub-station, Ponichak, Jammu to study the efficacy of various insecticides against the tomato fruit — borer, *Helicoverpa armigera* and rearing of the larvae was done at the Regional Agricultural Research Station, R.S.Pura, Jammu.

The vegetable Research sub-station is located at a distance of 7 Km from Jammu city. It lies at a latitude 32.42 ° North and a longitude 74.50 ° East, at an elevation of 295 metres above sea level. The topography of land is flat. Static ground water level is 4.35 metres with seasonal fluctuations of +30 cm. The climate of the experimental site in general is sub-tropical. May and June are the hottest months while December and January are the coldest. The annual rainfall ranges between 1000 to 1300 mm, of which 70 percent is received during monsoon. Winter rains are received during the month of January.

3.1 Evaluation of insecticides for the management of tomato fruit-borer, *H.armigera* on tomato (*L. esculentum*).

A field experiment was laid out at Vegetable Research Sub-station, Ponichak, Jammu during 1999. Tomato seedlings (Pusa Ruby) were raised in nursery and transplanted on 1-03-99 in randomized block design with eight treatments, including control, replicated thrice. The size of the plot was 3 x 2.25 metres with row

to row and plant to plant distances 60 and 45 cms, respectively. Recommended agronomic practices SKAUST were followed to raise a healthy crop.

The following treatments were evaluated against the tomato fruit-borer.

TREATMENT	CONCENTRATION (%)
Endosulfan (Thiodan 35 EC)	0.07
Malathion (Malathion 50 EC)	0.05
Carbaryl (Sevin 50 Wp)	0.10
Fenvalerate (Triumphcard 20 EC)	0.04
Cypermethrin (Cymbush 25 EC)	0.04
Decamethrin (Decis 2.8 EC)	0.0025
Dichlorvos (Nuvan 76 EC)	0.05
Control (water spray)	0.00

In all, crop was sprayed four times. First spray was applied at the initiation of flowers in the month of April (11- 4 - 99) and subsequent sprays were repeated at an interval of 14 days. Five hundred litres of emulsion per hectare was used for first two sprays and 600 liters of it was used for third and fourth sprays.

The observation were recorded for healthy and infested fruits from 5



Photograph showing the experimental field

randomly selected plants per plot at weekly intervals and percent fruit damage was worked out. The data of percent infestation was properly transformed and statistically analyzed as per Panse and Sukhatme (1985) in RBD to assess the efficacy of various insecticides and controlling the fruit damage by tomato fruit-borer (*H. armigera*).

3.1.1 Extent of damage by tomato fruit borer.

In order to study the percent infestation and percent loss in weight of tomato fruits, three plots (6 x 4.5m each) were selceted and number of healthy and infested (bored) fruits was recorded from three randomly selected plants at an interval of seven days from each plot. Percent infestation and percent loss in weight of tomato fruits was worked out following the procedure of the Singh and Singh (1975).

3.2 Collection, preservation and identification of larval parasites of tomato fruit borer.

Collection of parasitoids of tomato fruit-borer was made during the crop season 1999. In order to search for parasitoids, a regular monitoring was made during the growing period of the tomato crop. Larvae of *H. armigera* were collected from tomato field within the vicinity of the experimental site. The larvae were reared individually in small beakers, covered with muslin cloth and tied with rubber bands. Fresh tomato fruits were provided as food for larvae. Parasitoids emerging out from the larvae were collected and preserved in 70 percent ethyl alcohol. The specimen were got identified.

3.3 Computation of cost-benefit ratio of insecticides used

The yield of each plot to which insecticidal treatment was made and that of

control plots was recorded. There after, the yield and cost of each treatment was calculated on hectare basis. Then data was analyzed using the procedure of Singh *et.al.* (1983) to work out cost-benefit ratio.

*EXPERIMENTAL
FINDINGS*

4. EXPERIMENTAL FINDINGS

The results obtained during present investigations conducted in 1999 on management of tomato fruit-borer, *H. armigera* (Hubner) are presented in this chapter.

4.1 Evaluation of insecticides for the management of tomato fruit-borer, *H. armigera* on tomato (*L. esculentum*).

The efficacy of various insecticides against the tomato fruit-borer is presented in Table 1. No infestation was observed after first spray. After second spray the persual of the data revealed that all the insecticidal treatments were significantly superior over control. The per cent infestation of fruits varied from 14.5 to 23.9 per cent in various insecticidal treatments compared to 44.8 per cent in control. Cypermethrin (0.04%) was more effective than all other insecticidal treatments in reducing the fruit infestation, as the percent fruit damage in cypermethrin treated plots was 14.5 per cent. Malathion (0.05 per cent) and dichlorvos (0.05 per cent) were less effective in reducing the fruit damage as the per cent fruit damage was 23.9 and 22.3 percent, respectively. All the insecticidal treatments were identical and did not differ significantly from each other.

Likewise observations recorded after third spray, it was observed that all the insecticidal treatments were significantly superior over control in reducing the

Table 1 Efficacy of various insecticides against *H.armigera* on tomato fruit during 1999

Treatments	Concentration (%)	Percent fruit infestation after				Mean (%)
		Ist spray	2nd spray	3rd spray	4th spray	
Endosulfan 35EC	0.07	0.0	19.9 (26.16)	11.4 (19.50)	6.4 (11.96)	12.6 (19.21)
Malathion 50 EC	0.05	0.0	23.9 (28.83)	9.4 (17.32)	4.9 (10.18)	12.7 (18.78)
Carbaryl 50 WP	0.10	0.0	16.6 (23.87)	13.6 (21.50)	4.2 (9.59)	11.5 (18.32)
Fenvalerate 20 EC	0.04	0.0	16.6 (23.87)	11.4 (19.50)	5.3 (10.95)	11.1 (18.11)
Cypermethrin 25 EC	0.04	0.0	14.5 (22.33)	11.1 (19.42)	5.9 (11.57)	10.5 (17.75)
Decamethrin 2.8 EC	0.0025	0.0	15.8 (22.98)	4.1 (11.66)	2.8 (7.84)	7.9 (14.16)
Dichlorvos 76 EC	0.05	0.0	22.3 (27.94)	14.0 (21.96)	5.8 (11.29)	14.0 (20.40)
Control	Water spray	0.0	44.8 (42.00)	40.8 (39.71)	23.5 (28.93)	36.4 (36.88)
SE(m) ±	-	-	2.92	1.89	3.91	1.21
CD (p=0.05)	-	-	8.46	5.73	11.86	3.67

Mean of three replications

Observations recorded two weeks after the spray

Figures in paranthesis are angular transformation

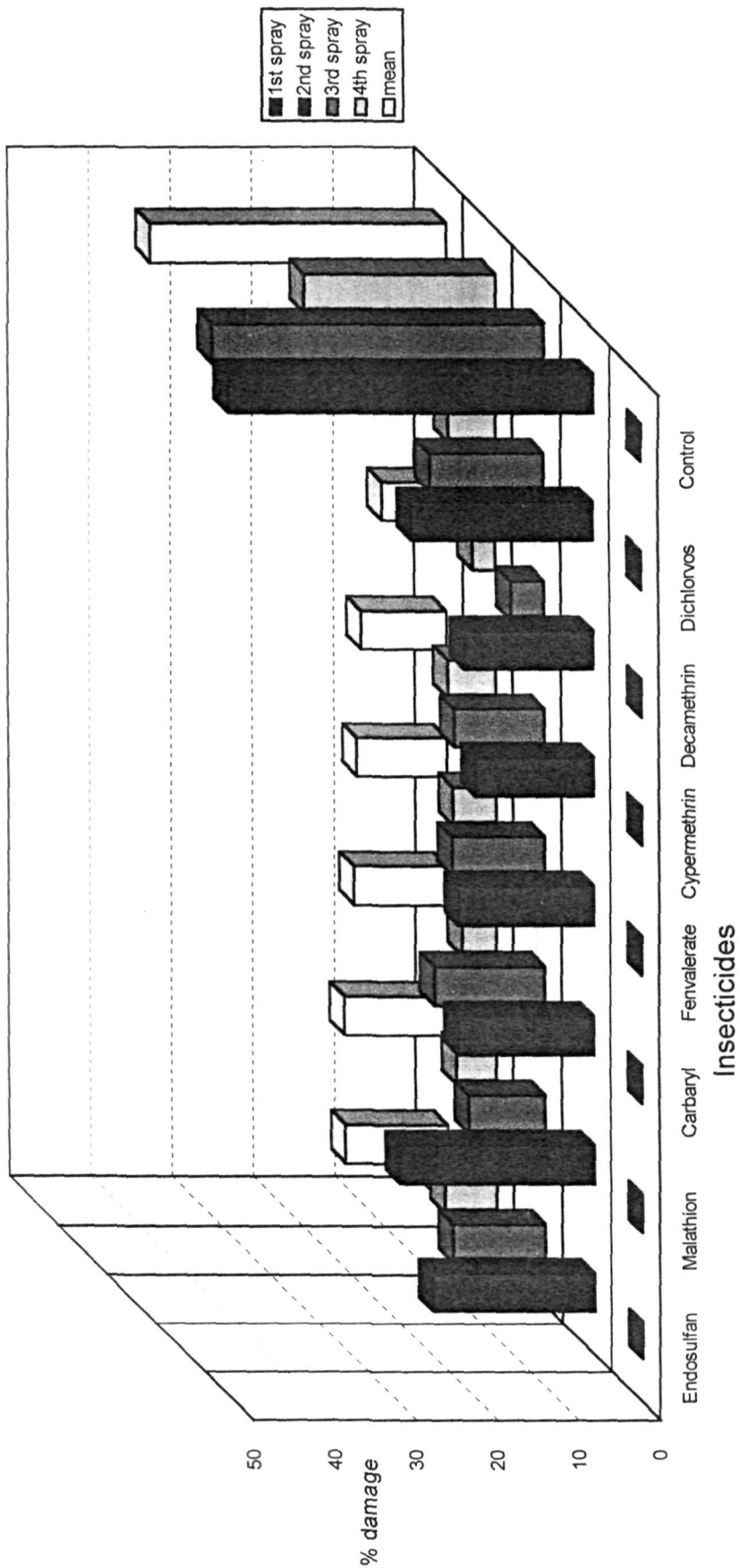
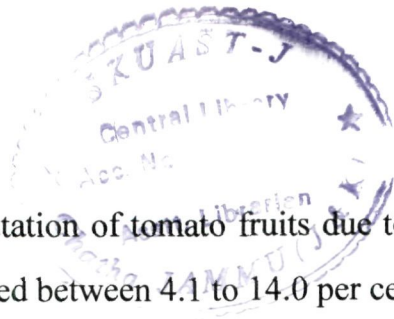


Fig 1 .Efficacy of insecticides against tomato fruit borer



infestation of tomato fruits due to borer attack. The per cent infestation of fruits ranged between 4.1 to 14.0 per cent in various insecticidal treatments compared to 40.8 per cent in control. Dichlorvos (0.05 per cent) was least effective than all other treatments whereas, decamethrin (0.0025 per cent) was highly effective. Decamethrin (0.0025 per cent) was significantly superior over rest of the insecticidal treatments but at par with malathion (0.05 per cent). Malathion (0.05 per cent), cypermethrin (0.04 per cent), fenvalerate (0.04 per cent), endosulfan (0.07 per cent), carbaryl (0.10 per cent) and dichlorvos (0.05 per cent) did not differ significantly from each other.

Similarly, in case of observations recorded after fourth spray, the infestation of fruits by tomato fruit borer varied between 2.8 per cent (minimum) to 6.4 per cent (maximum) in different insecticidal treatments compared to 23.5 per cent in control (water spray). All the insecticidal treatments proved significantly superior over control in reducing the borer damage. The treatment with decamethrin (0.0025 per cent) was highly effective, whereas treatment with endosulfan (0.07 per cent) was least effective in reducing the fruit damage. All the insecticidal treatments were at par with each other in reducing the fruit infestation.

The perusal of data reveals that overall performance of the insecticidal treatments was significantly superior over control in reducing the fruit borer damage during the period of investigation. The per cent infestation of fruits varied between 7.9 to 14.0 per cent in various insecticidal treatments, which was far less than the control (36.4 per cent).

It is clear from the data that decamethrin (0.0025 per cent) was the most effective insecticide in controlling the fruit damage, whereas, dichlorvos (0.05 per cent) was least effective treatment. Statistically decamethrin was at par with cypermethrin but significantly different from rest of the insecticidal treatments-- fenvalerate, carbaryl, endosulfan, malathion and dichlorvos. The order of efficacy was: decamethrin



Photograph showing healthy tomato fruits



Photograph showing damaged tomato fruits

>cypermethrin> fenvalerate> carbaryl> endosulfan> malathion> dichorvos.

4.1.1 Extent of damage by tomato fruit-borer.

The results of the experiment are presented in Table 2. The observations recorded at weekly intervals for a period of six weeks showed that the highest percent infestation (48.79) was recorded in 18th standard week while lowest (20.97) was recorded in 22nd standard week. The loss in fruit weight ranged from 16.14 to 40.96 per cent.

4.1.2 Role of abiotic factors on per cent infestation of tomato fruit borer

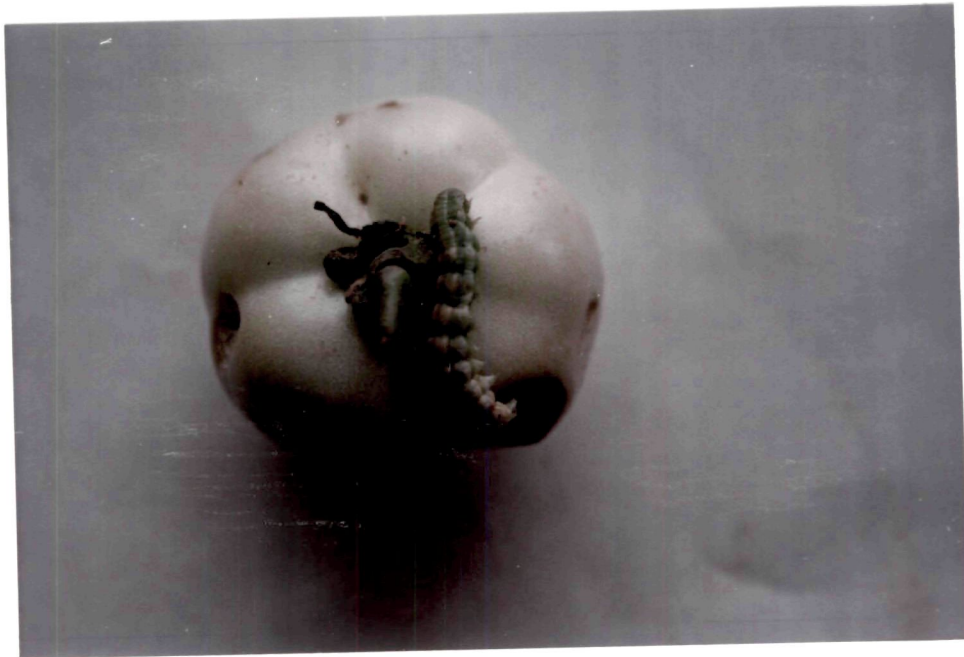
In order to study the extent of association of fruit borer infestation with respect to weather parameters, correlation analysis was worked out. As regards the relationship between weather parameters and per cent infestation of tomato fruits by *H. armigera* (Table 3), the results indicated that per cent infestation was inversely proportional to the maximum relative humidity and statistically significant. The other parameters showed non significant correlation. However, temperature(maximum and minimum), was positively correlated whereas,relative humidity(minimum) and rainfall was negatively correlated.

4.2 Collection, preservation and identification of larval parasites of tomato fruit-borer.

During the present investigations on pest-tomato interaction, a few parasitoids were found to be associated with the tomato fruit-borer, *Helicoverpa armigera*(Table 4). Among the parasitoids, the *Camponotus chloridae* Uchida (Hym.: Ichneumonidae) and *Chelonus blackburni* Cameron (Hym.:Braconidae) were found parasitising the tomato fruit-borer. A study was also conducted with regard to per cent parasitization of larvae and the data obtained is presented in Table 5.



Photograph showing parasitised larvae



Photograph showing the larva attacking tomato fruit

Table 2 Per cent infestation of tomato fruit borer (*H.armigera*) and relative yield loss during 1999

Standard weeks	Date of Observation	No. of Healthy fruits*	No. of infested fruits*	Infestation (%)	Weight of healthy fruits(Kg)	Weight of infested fruits(Kg)	Loss in weight (%)
18	1.5.99	7.00	6.67	48.79	0.245	0.170	40.96
19	8.5.99	11.67	8.33	41.65	0.408	0.212	34.19
20	15.5.99	21.67	10.33	32.28	0.758	0.263	25.76
21	22.5.99	15.00	6.33	29.68	0.525	0.161	23.47
22	29.5.99	32.67	8.67	20.97	1.143	0.220	16.14
23	5.6.99	29.67	9.00	23.27	1.061	0.229	17.75

* Mean values

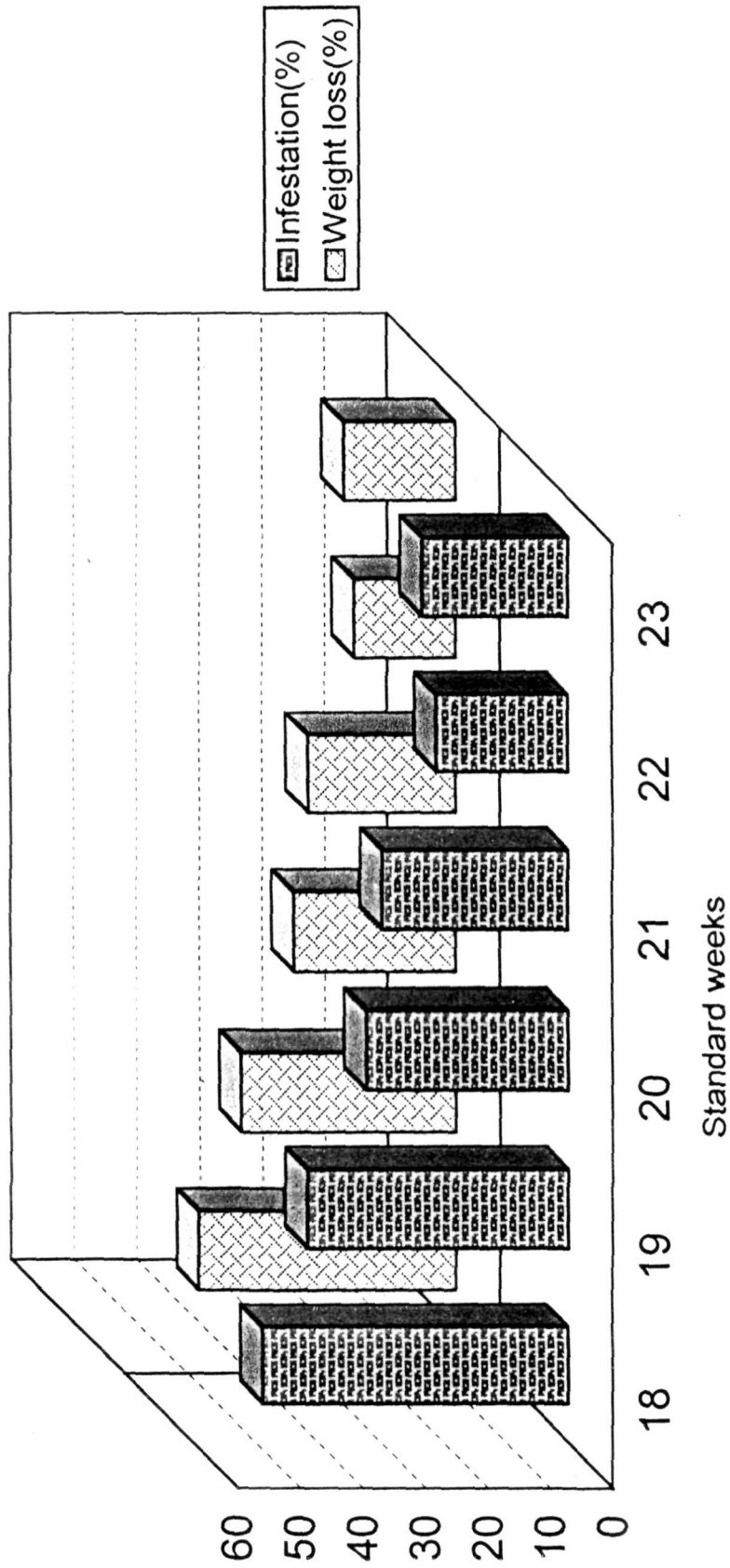


Fig. 2 Infestation of tomato fruit borer and relative yield loss

Table 3 **Correlation among various abiotic factors with per cent fruit infestation of tomato fruit-borer**

Variable	Temperature (°C)		Relative humidity		Rainfall (mm)
	Max.	Min.	Max.	Min.	
Infestation	0.21	0.66	-0.91*	-0.46	-0.69

*Marked correlation are significant at $P < 0.05$
N = 6

Table 4 Parasitoids of *Helicoverpa armigera* monitored on tomato during 1999

Order	Family	Scientific name
Hymenoptera	Ichneumonidae	Campolitis chloridae Uchida*
Hymenoptera	Braconidae	Chelonus blackburni Cameron**

* Larval parasitoid

** Egg larval parasitoid

Table 5 Field Parasitization of *H.armigera* on tomato during 1999

Standard weeks	<i>Campoletis chloridae</i> *		<i>Chelonus blackburni</i>	
	No. of Parasitoids	Per cent Parasitization	No. of Parasitoids	Per cent Parasitization
13	2	4	0	0
14	1	2	0	0
15	3	6	0	0
16	0	0	0	0
17	5	10	0	0
18	7	14	1	2
19	3	6	1	2
20	2	4	2	4
21	1	2	0	0
22	0	0	0	0
23	0	0	0	0

* Puparium

The information based on the data collected out of a cohort of 50 larvae under the laboratory conditions revealed that the parasitoid *C. chloridae* Uchida was recorded throughout the cropping season, except with the interruption of a few weeks. *C. blackburni* Cameron was found parasitizing the pest in the peak season of the cropping stage.

Of the two parasitoids, *C. chloridae* was more active. As far as the trend of parasitization was concerned, this revealed high incidence of parasitism (10-14 per cent) in 17th and 18th standard week. However, low incidence of parasitism (2-6 per cent) was observed from 13th to 16th standard week and again from 19th to 21st standard week. The highest parasitism (14 per cent) was observed in 18th standard week. No parasitism was recorded in 16th, 22nd and 23rd standard week.

The trend of parasitism showed that the rate of parasitism increased with the increase in maximum temperature then decreased and no parasitism was observed at the last stage of the crop.

The parasitism of *C. blackburni* (an egg-larval parasitoid) was observed from 18th to 20th standard weeks, when the fruiting was at its peak. The extent of parasitism was 2-4 per cent. There was no parasitism during lean periods of the tomato fruiting. *C. chloridae* was found active both in vegetative as well as in the reproductive stages of the crop, whereas, *C. blackburni* was active only in the reproductive stage of the tomato crop.

4.2.1 Role of abiotic factors on per cent parasitism of tomato fruit borer

In order to ascertain the role of abiotic factors on the per cent parasitism of tomato fruit borer, correlation analysis was worked out between the weather parameters

and per cent parasitism. The correlation results as presented in Table 6 reveal that the correlation coefficients thus obtained were non-significant. However, maximum and minimum temperature was positively correlated whereas, relative humidity and rainfall showed negative correlation.

4.3 Computation of cost benefit ratio of the insecticides used.

4.3.1 Effect of insecticidal treatment in production of marketable fruits

The data presented in Table 7 showed that all the insecticides were significantly superior over control in production of marketable fruits. The control plots (sprayed with water) yielded 55.55 quintals of marketable tomato fruits per hectare whereas, those treated with various insecticides resulted in production of marketable fruits between 95.70 to 130.96 quintals per hectare. The maximum yield was obtained from decamethrin (0.0025 per cent) treated plots to the tune of 130.96 quintals per hectare. The lowest yield (95.7 q/ha) was obtained from dichlorvos (0.05%) treated plots. The other treatments were intermediate between the two but superior over control. Decamethrin was significantly superior over dichlorvos and malathion but did not differ significantly from rest of the treatments.

4.3.2 Cost benefit ratio.

To accomplish this parameter, the weight of marketable fruits per plot was recorded. The production of healthy fruits in quintals per hectare was calculated on the basis of mean of three replications. The cost of marketable tomato fruits at the rate of Rs. 500/qa and cost of each treatment (pesticide + labour charges) was also worked out. Then net gain was calculated by deducting the cost of treatment from total cost of the marketable fruits. Cost benefit ratio was calculated for each

Table 6 Correlation among various abiotic factors with per cent parasitism of tomato fruit-borer

Parasitoids	Temperature (°C)		Relative humidity (%)		Rainfall (mm)
	Max.	Min.	Max.	Min.	
<i>Camponotus chloridae</i>	0.30*	0.26*	-0.54*	-0.34*	-0.47*
<i>Chelonus blackburni</i>	0.38*	0.41*	-0.59*	-0.39*	-0.24*

* Non significant N=11

Table 7 Effect of insecticidal treatments on the yield of tomato fruits during 1999

Treatment	Concentration (%)	Average fruit yield (kg/plot)	Yeild (q/ha)
Endosulfan 35 EC	0.07	8.10	120.00
Malathion 50 EC	0.05	7.14	105.77
Carbaryl 50 WP	0.10	7.85	116.29
Fenvalerate 20 EC	0.04	7.60	112.59
Cypermethrin 25 EC	0.04	7.80	115.55
Decamethrin 2.8 EC	0.0025	8.84	130.96
Dichlorvos 76 EC	0.05	6.46	95.70
Control	Water spray	3.75	55.55
SE(m) \pm		0.56	
CD (P=0.05)		1.69	

insecticide. The persual of the data in Table 8 clearly shows that all insecticidal treatments controlled the incidence of borer damage thereby, increasing the fruit yield. However, considerable differences were observed among various insecticidal treatments. Net gain in decamethrin treated plots was maximum (Rs. 35860), whereas it was minimum (Rs. 20075) dichlorvos treated plots.

The cost benefit ratio ranged between a minimum of 1:7.75 (cypermethrin, 0.04 per cent) to a maximum of 1:24.73 (malathion, 0.05 per cent). The order of ranking was malathion (1:24.73) > decamethrin (1:19.44) > dichlorvos (1:17.64) > endosulfan (1:13.50) > carbaryl (1:13.03) > fenvalerate (1:11.19) > cyprmethrin (1:7.75).

The studies pertaining to economics of various insecticidal treatments indicate that the plots treated with malathion and decamethrin gave higher net gain than any other treatment. Maximum net returns per rupee invested were recorded in malathion treatment (Rs.24.73). Decamethrin was next in order (Rs.19.44), when cost benefit ratio was compared. Minimum net returns per rupee (1:7.75) invested was got in cypermethrin treated plots due to high cost of the insecticides. Thus it is evident that malathion, decamethrin and dichlorvos were the best insecticides in terms of cost benefit ratio and could be safely recommended against tomato fruit borer on tomato crops.

Table 8 Economics of insecticidal treatments against tomato fruit borer, *H. armigera* during 1999

Treatment	Concentration (%)	Yield (q/ha)	Increase in yield over control (q/ha)	Cost of treatments* (Rs/ha)	Gain due to treatments @ Rs.500/q	Net gain over control (Rs./ha)	Cost benefit ratio
Endosulfan 35 EC	0.07	120.00	64.45	2221.20	32225.00	30003.80	1:13.50
Malathion 50 EC	0.05	105.77	50.22	976.00	25110.00	24134.00	1:24.73
Carbaryl 50 WP	0.10	116.29	60.74	2164.00	30370.00	28206.00	1:13.03
Fenvalerate 20 EC	0.04	112.59	57.04	2340.00	28520.00	26180.00	1:11.19
Cypermethrin 25 EC	0.04	115.55	60.00	3429.00	30000.00	26571.00	1:7.75
Decamethrin 2.8 EC	0.0025	130.96	75.41	1845.00	37705.00	35860.00	1:19.44
Dichlorvos 76 EC	0.05	95.70	40.15	1076.76	20075.00	18998.24	1:17.64

Tomato yield in unsprayed control was 55.55 kg.

*Insecticide + Labour charges.

DISCUSSION

5. DISCUSSION

The results of the present investigations on the management of tomato fruit borer, *Helicoverpa armigera* (Hubner), presented in the preceeding chapter, are discussed here under.

5.1 Evaluation of insecticides for the management of tomato fruit borer, *H. armigera*, on tomato (*L. esculentum*).

The efficacy of various insecticidal treatments against tomato fruit borer was evaluated after each spray, from fruit setting stage. In general, the efficacy of insecticides is judged on the basis of its ability to protect the crop for a reasonable period from the target insect pest by causing a considerable reduction in the population of the said pest. The efficacy of seven insecticides namely : endosulfan (0.07 per cent), malathion (0.05 per cent), carbaryl (0.10 per cent), fenvalerate (0.04 per cent), cypermethrin (0.04 per cent), decamethrin (0.0025 per cent) and dichlorvos (0.05 per cent) was studied against tomato fruit borer.

Among the various insecticides evaluated against tomato fruit-borer, decamethrin (a synthetic pyrethroid) was found significantly superior to rest of the insecticides and control but at par with cypermethrin. Dichlorvos (0.05 per cent) was least effective as compared to other insecticidal treatments, but

significantly superior over control. The order of efficacy was, decamethrin > cypermethrin > fenvalerate > carbaryl > malathion > endosulfan > dichlorvos.

The results obtained are in agreement with the findings of Singh and Narang (1990) , who evaluated six insecticides and found that decamethrin, cypermethrin, permethrin and fenvalerate either at the rate of 50g active ingredient per hectare or 20g active ingredient per hectare of decamethrin gave better protection of tomato fruits from the borer infestation compared to carbaryl and endosulfan at high dose of 1000 and 700g active ingredient, respectively. Among these insecticides, decamethrin (0.002 per cent) was outstanding with 3.4 per cent fruit infestation as against 51.2 per cent in control. Similar results were obtained by Sharma *et. al.* (1992), who evaluated four synthetic pyrethroids and carbaryl, and found that decamethrin was most effective in reducing the borer infestation.

Subsequently Mehta *et. al.* (1991) also confirmed that cypermethrin (0.04 per cent) was most effective having lowest damage and highest yield. Likewise Talekar *et. al.* (1991) observed that fenvalerate at the rate of 12g active ingredient per hectare was most effective treatment against the *H. armigera* in terms of per cent infestation and yield.

Abrol and Bhat (1996) evaluated four insecticidal treatments and found that cypermethrin (0.04 per cent) at the rate of 1.5 ml per litre of water to be significantly effective against tomato fruit borer with 4.29 per cent fruit infestation compared to 17.78 per cent in case of control. Atwal and Dhaliwal (1997a) are also in agreement with present findings and recommended 2.5 litres of endosulfan 35 EC or 250 ml. of fenvalerate 20 EC or 200 ml of cypermethrin 25 EC and 400 ml. of deltamethrin 25 EC in 625 litres of spraying fluid per hectare to control the fruits infestation and to increase the yield of marketable tomato fruits.

5.1.1 Extent of damage by tomato fruit borer

In the present investigations, it was observed that on an average 32.77 per cent of tomato fruits were infested by the tomato fruit borer, *H. armigera*, resulting in a loss of 26.38 per cent in the weight of tomato fruits. The present findings are in line with the findings of several earlier workers. Five to twenty five per cent of fruits in commercial tomato growing areas were damaged by the borer in the California (U.S.A.). It was further reported that the substantial loss was due to the habit of damaging several fruits without completely devouring the infested fruits and sometimes 50-60 per cent of the tomato fruits were attacked (Anon., 1936). Srinivasan (1959) reported that tomato fruit borer was a serious pest of tomato in Tamil Nadu causing a loss of 40-50 per cent. Parkash *et. al.* (1979) reported a total loss of 21.5 per cent during March - May crop due to attack on flowers and fruits in Haryana state. Singh and Narang (1990) reported 50-100 per cent loss of fruits due to borer attack. Similarly, Abrol and Bhat (1996) reported 17.78 per cent fruit damage in control plots.

The actual loss in weight is much more than what is indicated, because in the absence of fruits, the borer infested flower buds and flowers, thus prevented the formation of fruits (Prakash *et. al.*, 1979). The variations in fruit infestations could be due to different agro-climatic conditions, time of sowing and harvesting of the crop.

5.1.2 Role of abiotic factors on percent infestation of tomato fruit borer.

Tripathi and Singh (1989) reported that build up of the pest population was mainly influenced by abiotic factors. The temperature ranges, 28.4 to 41.9 °C during May - June coupled with low relative humidity, adversely affected the pest

population. The optimum temperature for the multiplication of the pest is 22°C. It is reported by Hmimina (1984) that period of rainfall had a definite bearing on pest population. Kaur (1995) observed that a rise in temperature in early stages (11th - 20th Feb.) and periodic rains during March led to a very high build up of the pest population during the peak fruiting period of the crop in the year 1993. However, during the year, 1994 the rains in the month of February brought the temperature down (mean daily temperature 12.12 to 15.9°C) and as a result, there was a low level of pest population at the peak flowering and fruiting period of the crop. The present findings that infestation of tomato fruit borer, was inversely proportional to maximum relative humidity, are also in direct agreement to the studies of Yadav and Lal (1988), who inferred that pest population was positively correlated with temperature and negatively with relative humidity.

5.2 Collection, preservation and identification of larval parasites of tomato fruit borer.

Among the various insect pests attacking the tomato crop, fruit borer, *H. armigera* was the most serious one inflicting heavy damage at the larval stage. Attempts in the past were made to study the natural enemies of the this insect pest and inoculative studies were also made by utilizing a number of parasitoids. The data which deals with the parasitoid complex associated with the said pest and quantitative estimation made on parasitism of *H. armigera*, is discussed here as under :

Out of two parasitoids encountered in the present study, *Campoletis chloridae* Uchida (Ichneumonidae) was observed as the voracious natural enemy of tomato fruit borer. According to Singh (1988), it is most widely distributed parasitoid from the Himalaya to the sea level and parasitism exceeds 35 to 83 per cent.

In the present study, the initial parasitism by this parasitoid was encountered

in the 13th standard week and the extent of parasitism was low. Highest parasitism was observed in the 18th standard week. No parasitism was observed in the 16th, 22nd and 23rd standard weeks. The highest per cent parasitism (14 per cent) was observed in the 18th standard week(1st week of May). This is in contrast to the findings of Sivaprakasam (1997) , who reported high parasitization(26.18 per cent) during first week of April. This may be due to different agro-climatic conditions, time of sowing and harvesting. Mani(1980) also reported high parasitism of tomato fruit borer larvae by *Campoletis chloridae* in the month of April.

In the beginning the per cent parasitism was low (4-6 per cent) from 13th to 15th standard weeks. Then it increased and was highest (10-14 per cent) in the 17th and 18th standard week. It started declining from 19th standard week and there was no parasitism in the last stage of the crop. The statement of Ravi and Verma (1997) is in line with the present findings that the parasitism remains low in the initial stage, gradually increases and then declines with rise in temperature. It was quantitatively evaluated that throughout the cropping season, the parasitism by *C. Chloridae* of *H. armigera* larvae was 2-14 per cent.

Another parasitoid, *Chelonus blackburni* Cameron (Braconidae) was observed parasitizing the host, tomato fruit borer. It was quantitatively evaluated that throughout the cropping season, the extent of parasitism was very low, 2-4 per cent. But it was important to note that this parasitoid did not appear during the initial and last stage of cropping season. It only appeared during the peak period of the fruiting stage, from 18th to 20th standard week. Range of parasitism observed during this period was 2-4 per cent . The parasitoid though appeared for a short time and that too, to a lesser extent, still can not be ignored due to its appearance during the peak population of the insect pest as well as peak fruiting stage of the crop. *C. Chloridae* was present in the vegetative as well as in the reproductive stage of the crop. This is in

conformity with the observations of Atwal and Dhaliwal (1997a). On the other hand *C. chelonus* was present only in the reproductive stage of the crop.

Finally, it can therefore, be inferred from the above discussion that these parasitoids may prove to be a potential source for suppressing the population of tomato fruit borer, if manipulated according to specifications.

5.2.1 Role of abiotic factors on percent parasitism of tomato fruit borer.

From the perusal of the results in Table 6, it is evident that the parasitism of the tomato fruit borer was positively correlated with temperature and negatively with relative humidity and rainfall. However, when all the weather parameters were individually taken into consideration, they showed no significance with parasitism of the pest. However, the studies made by Yadav and Lal (1988), reveal that population of *H. amigera* was positively correlated with temperature (maximum and minimum) and negatively with relative humidity and per cent parasitism.

5.3 COMPUTATION OF COST BENEFIT RATIO OF THE INSECTICIDES USED.

5.3.1 Effect of insecticidal treatments in production of marketable fruits.

The data presented in Table 7 depicted that all the insecticidal treatments were significantly superior in reducing the fruit damage and production of marketable tomato fruits as compared to control. Highest yield of 130.96 quintals per hectare was obtained from the plots treated with decamethrin (0.0025 per cent) whereas, lowest yield (95.70 q/ha) was obtained from dichlorvos (0.05 per cent) treated plots. However, all insecticidal treatments were highly effective than control, which produced

55.55 quintals of marketable tomato fruits per hectare. Similar observations have been recorded by several earlier workers. However, there was a great diversity in the yield (q\ha) obtained by various workers. The difference between the present investigations and the reported values may be due to different agro-climatic conditions, cultural practices and experimental conditions.

5.3.2 Cost benefit ratio

All the insecticidal treatments were found to be highly effective in decreasing the incidence of pest damage at varying degrees thereby, increasing the yield of tomato fruits. The cost benefit ratio ranged between a minimum of 1:7.75 (cypermethrin, 0.04 per cent) to a maximum of 1:24.73 (malathion, 0.05 per cent). Decamethrin (0.0025 per cent) and dichlorvos (0.05 per cent) were next in rank to malathion with a cost benefit ratio of 1:19.44 and 1:17.64, respectively. Thus, it is clear that malathion ranked first in terms of cost benefit ratio. But this is in contrary to the values regarding the cost benefit ratio recorded by Singh and Narang (1990) where permethrin (a synthetic pyrethroid) ranked first with a cost benefit ratio of 1:25.10. In the present findings maximum net returns per rupee in case of malathion treated plots, was due to low cost of the insecticide, whereas minimum net returns per rupee in case of cypermethrin was due to high cost of the insecticide.

SUMMARY
AND
CONCLUSION

6. SUMMARY AND CONCLUSIONS

Keeping in view the economic importance of tomato fruit borer, *H. armigera* (Hubner)(Lepidoptera: Noctuidae), studies were undertaken to work out its management under subtropical agroclimatic conditions of Jammu district.

Studies on evaluation of insecticides against tomato fruit borer, revealed that all the insecticidal treatments were significantly superior in reducing the infestation and fruit damage compared to control (water spray). However, the various treatments varied in their effectiveness from one another. Out of seven insecticides evaluated, decamethrin (0.0025 per cent) was most effective and dichlorvos (0.05 per cent) least effective. The relative efficacy of various insecticides was in the order of decamethrin > cypermethrin > fenvalerate > carbaryl > endosulfan > malathion > dichlorvos. The per cent infestation and loss in weight of tomato fruits was 32.77 and 26.38 per cent, respectively.

It is said that natural enemies always have a bearing on the population dynamics of a pest. It is also well known that extent of natural enemies is inversely proportional to the incidence of the pest, on which it parasitizes. In the present findings, two parasitoids, *C. chloridae* (Ichneumonidae) and *C. blackburni* (Braconidae) were found parasitising the pest during the cropping season. *C. chloridae* had a high voracity of parasitism (14 per cent) during first week of May

1999. The parasitoid remained active for a maximum period of crop, from vegetative to the fruiting phase. The incidence of parasitism was irregular- low, high, low and disappeared during the last stage of the crop. Another parasitoid, *C. blackburni* was less virulent (2-4)per cent). It appeared only at the peak fruiting stage and was totally absent during the vegetative as well as the last stage of the tomato crop.

The marketable fruit yield of tomato was highest in plots treated with decamethrin (0.0025 per cent) and lowest in dichlorvos (0.005 per cent). The relative efficacy of various insecticidal treatments in respect of yield was in the order : decamethrin > endosulfan > carbaryl > cypermethrin > fenvalerate > malathion > dichlorvos. The highest net returns of Rs. 35860 was recorded in case of decamethrin treatment.

The data on cost benefit ratio revealed that control plots produced 55.55 quintals of healthy fruits per hectare as compared to those treated with various insecticides where the production ranged between 95.70 to 130.96 quintals per hectare. The cost benefit ratio ranged between a minimum of 1:7.75 (cypermethrin 0.04 per cent) to a maximum of 1: 24.73 (malathion 0.05 per cent); the rest of the insecticides being intermediate between the two. It is evident on the basis of cost benefit ratio that spraying of malathion (0.05 per cent) was found to be the most economical as it gave maximum returns of 24.73 per rupee invested. Decamethrin (0.0025 per cent) was next in order, which gave a net return of Rs. 19.44 per rupee invested.

It is clear from the that decamethrin (0.0025 per cent) was the most effective insecticide in controlling the fruit infestation and thereby, resulted in higher yield of tomato fruits. Economic returns per rupee invested were also higher in decamethrin treated plots, though highest cost benefit ratio was obtained from malathion treated plots. As far as parasitism of tomato fruit borer is concerned, if

parasitoids are manipulated according to specifications these might prove a potential source of suppressing the population build up of *H. armigera* without contaminating the environment.

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Appendix 1 Weekly weather data of WMRC, Ponichak during crop season, 1999

Standard Weeks	Rainfall (mm/wk)	Relative humidity (%)		Temperature(°C)		Sunshine (hrs/day)
		Max.	Min.	Max.	Min.	
05	3.2	90.1	80.8	17.1	3.6	9.0
06	1.2	88.6	83.1	19.6	5.1	5.0
07	0.0	87.1	82.4	22.4	8.1	6.1
08	18.8	86.8	81.6	21.8	8.1	6.2
09	0.0	87.8	80.9	22.9	6.4	7.6
10	20.3	92.7	78.5	23.3	9.6	6.1
11	0.0	93.1	76.5	24.9	7.9	8.4
12	0.0	91.9	76.9	25.0	8.4	8.1
13	0.0	93.3	77.0	30.2	9.8	8.9
14	0.0	90.9	74.1	32.3	11.4	8.6
15	0.0	88.2	71.1	34.2	15.4	8.6
16	0.0	87.71	69.5	37.1	12.9	10.9
17	0.0	88.1	63.9	39.0	15.1	11.7

18	0.0	78.1	61.5	39.6	21.0	10.4
19	2.1	81.6	62.3	35.5	19.6	9.4
20	0.0	85.1	65.4	38.6	17.6	11.7
21	1.7	85.2	62.8	36.7	20.1	8.5
22	12.2	85.7	61.7	38.4	17.7	10.9
23	23.6	90.1	70.1	36.4	19.3	10.8
24	0.0	85.9	60.4	39.4	22.9	11.4
25	146.0	88.9	74.4	35.1	21.9	9.5

* Mean of week.