POPULATION DYNAMICS OF *Helicoverpa armigera* (HUB.) (LEP; NOCTUIDAE) ON CHICKPEA (*Cicer arietinum* L.)

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THESIS

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ABSTRACT

The experiment was conducted during rabi, 1998-99 at Dryland Agricultural Research Station, Dhiansar. The investigations were carried out under the following heads:

1. Estimation of population
2. Life-table studies (Stage specific)
3. Survey of parasitoids

The present investigation on the management of major insect-pest, *Helicoverpa armigera* (Hub.) on chickpea, an inventory was made on the population dynamics under varying weather factors in the prevailing agro-climatic conditions at Dhiansar, Jammu. The observations revealed that the sampling technique by Ground Cloth-Shake Method (GCSM) was found to be more efficient, accurate and practical than Visual Count Method (VCM) and sample unit size of 1.0 m row length was more precise than 0.5 m and more economical than 1.5 m row length.

The life-table (stage specific) with respect to various developmental stages for the four consecutive generations revealed that the trend index value (I) was more than unity in the fourth generation while in other generations I-value was observed to be less than unity. Further, the generation survival (S_G) in the fourth generation was found

to be corresponded well to the I-value. This indicates that the mortality factors operating during this period were not very effective in causing a decline in pest population, thus warranted to apply control measures. In rest of the generations the I-values were negative and hence no control measure was necessary.

During the present investigation on pest-chickpea interaction, a few parasitioids were collected which belongs to the order Hymenoptera viz., *Campoletis chloridae* Uchida (Family: Ichneumonidae), *Tetrastichus ayyari* Rohwer (Family: Eulophidae) and a Tachinid (Indet.) (Family: Tachnidae) of the order Diptera. The information based on the data revealed that the *C. chloridae* made its presence felt almost throughout the cropping seasons, whereas, the rest were seen parasitizing at the late stage of the crop.

The vagaries of weather parameters on the incidence of pod-borer clearly indicate that the max. temp was positively correlated and RH (min.) was negatively correlated with the pest population.

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Correction Certificate

This is to certify that all the corrections/suggestions made by the external examiner during the viva voce examination of Mr. **Som Nath Sharma** student of M.Sc. Agri. (Entomology) (**Regd. No.97/A/492/M**) for thesis entitled **"Population dynamics of *Helicoverpa armigera* (Hub.) (Lep., Noctuidae) on chickpea (*Cicer arietinum* L.)"** have been incorporated before final binding of the thesis.

Tasawwar Husain
(Dr. Tasawwar Husain)

Major Advisor &
Coordinator

CERTIFICATE - I

This is to certify that the thesis entitled **"Population dynamics of *Helicoverpa armigera* (Hub.) (Lep., Noctuidae) on chickpea (*Cicer arietinum* L.)"**, submitted in partial fulfilment of the requirements for the degree 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 *bona fide* research carried out by **Mr. Som Nath Sharma** 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.

CHAIRMAN
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CERTIFICATE - II

We, the members of the Advisory Committee of **Mr. Som Nath Sharma**, a candidate for the degree of Master of Science in Agriculture (Entomology), have gone through the manuscript of the thesis entitled, **"Population dynamics of *Helicoverpa armigera* (Hub.) (Lep., Noctuidae) on chickpea (*Cicer arietinum* L.)"** and recommend that it may be submitted by the student in partial fulfilment of the requirements for the degree.

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dedicated
to the
sweet memories
of
my
father and mother

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INTRODUCTION

1. INTRODUCTION

Chickpea (*Cicer arietinum* L.) commonly known as Bengal gram, Egyptian pea, Spanish pea, Chestnut pea (All in English). Homer (Arabic), Grao-de-bico (Portuguese), Garbanzo or/garavance (Spanish) and in Indian Languages-Chana, (Hindi), Shola (Dogri) Chann (Kashmiri). Butmah (Assamese), Sonamug (Bengali), Mung (Oriya), Pachapesalu (Telgu) and Pasipayru (Tamil), in different parts of the country, has been under cultivation in India since antiquity. It can be called as one of the earliest of domesticated plants.

The scientific name of Chickpea, *Cicer arietinum* L . has been derived from the Roman word 'Cicer' owing to the resemblance to head of a 'ram'and the word 'arietinum' from 'aries' meaning 'ram'.

It is believed that the origin of chickpea is in South Asia, and is one of the oldest pulse crop known and cultivated in Asia and Europe and was known to the ancient Egyptians, Greeks and Hebrews. It has been found in pre-historic sites in the Mediterranean area (Kochhar, 1981). Helback (1966) has reported the occurrence of archeological remains of chickpea dated to 5450 BC at Hacilar in Turkey and Ca 4000 BC from Palestine. Chickpea has been introduced all over the world including America, Africa and Australia.

It is a versatile crop among the grain legumes and ranks first among the pulses both in acreage and production. Of the total world production, 5,800,000 t i.e 70 per cent was shared by India, in 1974

(Kochhar, 1981). The total acreage of world chickpea production was 10.4 million hectares (Singh, 1988). Of the total world area (10.3 m ha) under chickpea, 7.9m ha (about 77 per cent) is in India. This area account for about 33 per cent of the total pulse acreage (23.3 m ha) and about fifty per cent of the total production (11.5 m tonnes) during the year 1985-86 (Padmana Bhan, 1989; Jaswani and Baldev, 1990) and the producers of chickpea in order of importance are India, Pakistan, Ethiopia, Turkey, Burma and Moracco.

In India the total production of food grains was 130.5 million tonnes, out of this, pulses only contributed 12.01 m t during 1978-79. The production of cereals increased by 120 per cent since 1950-51, but the production of pulses has remained more or less static (Singh, 1988).

India ranks first in the world in respect of production as well as in acreage. Of the total world area (10.6 m ha) under chickpea, 8.48 m ha (80 per cent) is in India, where it accounts 28.5 per cent of the area and 37.5 per cent of the production of total pulses grown in this country (Sharma, 1995).

Inspite of the great importance, the area under chickpea cultivation has remained almost static since the last 13 years (Sandhu *et al.*, 1984), and the average annual productivity of the crop in India was reported to be 740 kg/ha as against 1770 kg/ha in Israel and 1660 kg/ha in Egypt (FAO, 1985). This adverse competition from high yielding cultivars of cereals arising from the extension of irrigation network in northern India in post-green revolution period bringing about marked shift from pulses to wheat and rice (Grewal, 1988). The production pattern of chickpea has also got affected due to the fact that the marginal lands where chickpea was grown in the past and hitherto not fit for cereal cultivation, were diverted to wheat cultivation due to assured yields and high economic returns to the growers (Singh, 1988).

In India major chickpea producing states are MP, Rajasthan, U.P, Haryana, Maharashtra and Punjab. Jammu and Kashmir during 1978, had an area of 2.9 thousand hectare with the yield 552 kg/ha and production 1.6 thousand tonne (Annon, 1978), whereas in 1979 had an area of 4.4 thousand hectares under gram with the production of 2.7 thousand tonne (Singh, 1988). However, no recent data pertaining to the production and acreage of chickpea in J&K is available.

Among the several factors, susceptibility of chickpea to various insect pest-complex appears to be a single most important factor for serious yield reduction and instable production of the crop. This crop is attacked by more than thirty six species of pests in India (Nayar *et al.*, 1982 and Davies and Latief, 1977). Among these pests, the gram pod-borer is the most serious (Choudhary and Choudhary, 1975 and Chhabra, 1980; Rai and Singh, 1976; Rawat *et al.*, 1979; Subramanium *et al.*, 1976)

Helicoverpa armigera (Hubner) [Noctuidae: Lipidoptera], commonly known as gram pod-borer has a wide distribution occurring throughout 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 a pest of great economic concern because of its damaging potential and host-plant range causing serious damage to about 96 cultivated and 61 wild species in India (Bhatnagar and Davies, 1978). In another report it infest 181 cultivated and uncultivated plant species (Manjunath *et al.*, 1985). Being polyphagous in nature, the pest feeds on a wide variety of crops of economic important, other than chickpea, such as cotton, tobacco, wheat, maize, sorghum, pea, arhar, groundnut and beanpods. Some important vegetables like tomato and Okra are also badly destroyed by this pest in the field (Vaishampayan and Veda, 1980) A single larva of pod-borer can damage 25-30 pods of gram in its life-time (Sharma, 1978). In India about 90-95 per cent loss in the yield of chickpea by this pest alone has been reported by Sexena (1978), Sithanantham *et al.*, (1983) and Sachan and Katti (1994). The loss may exceed to even 330 million dollars annually (Reed and Pawar, 1982).

As far as the systematic position of *armigera* species is concerned, originally it was described under the genus *Heliothis*. Later on, Hardwick raised a new genus *Helicoverpa* in 1965 and transferred to it some of the species of *Heliothis* including armigera. However the editor of the review of Applied Entomology commented (Vol-53, Ser. A, part 12, p. 620) that this view was not shared by Boursin, who synonymised *Helicoverpa* with chloridae and preferred to use the name

Heliothis to include those species for which Hardwick had erected *Helicoverpa*. In the present study, the name *Helicoverpa armigera* has been retained since the systematic position of *armigera* species has not been resolved.

A perusal of the available literature reveals that while enormous information is available on various aspects of gram pod-borer with regard to chickpea crop, it becomes imperative to carry out detailed investigation with the objective deciphered in the following paragraphs:

H. armigera was reported to have five generations on various crops in U.P during December to March (Tripathi and Sharma, 1985), one generation on chickpea in Punjab during April-May. (Singh and Singh, 1975; Singh *et al.*, 1990). While in Hissar, pod borer ravaged gram during August-September and the density was less than 0.81 larva per sq. m at vegetative stage which increased to 19.02 at pod-formation stage (Kaushik and Naresh, 1984). The data indicated that late sowing of chickpea got adversely affected by *H. armigera* and this view confirmed the work of Sachan (1987). So the use of early maturing varieties should be encouraged to avoid damage by *H. armigera* as the pod-setting would coincide with low level of larval population.

Lal *et al.*, (1980) studied the relationship between the percentage pod-damage and sowing dates of chickpea and found that the pest infestation was not solely responsible to the reduction in yield in the late sowing.

From the foregoing discussion it was felt germane to study the estimation of population of gram pod-borer on chickpea. The estimation of population (pest density) is needed in relation to crop yield reduction, so as to develop and utilize effective management procedures through the required sampling phenomenon and classify the infestation as high or low and take a decision whether the field needs to be treated or not. This plan can be useful in indicating, whether, the true mean population is less than or equal to be resorted to or the true mean is equal to or greater than the upper level of infestation needs control measures. The application of pesticides can then be made when warranted by economic infestation level. This would help in minimizing the use of chemicals.

The objective of another study was to collect appropriate informations for the study of life-table and also a general survey had been conducted to get the informations about the extent of parasitization by the parasitoids on the gram pod-borer. To accomplish the present investigation under the Jammu based agro-climatic conditions for the chickpea crop, a work plan was chalked out to study *H.armigera* under the following heads.

1. Estimation of population.
2. Life-table studies (Stage specific).
3. Survey of parasitoids.

It is hoped that this project might yield some scientific ideas to fill in the depth between the realisable potential and the actual current productivity levels of chickpea crop, in order to boost up the production and acreage in J&K state. Further, it augurs well that the information elicited, thus will be of immense use in various other Chickpea growing areas, so that it can put the chickpea production in our country on a very sound footing.

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REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

2.1 POPULATION DYNAMICS

The study of population dynamics is to develop and utilize effective pest management procedures and for this, information is needed on crop yield and reduction relative to pest density. The ability to determine an economic threshold of an insect-pest on a crop is dependent on distinguishing the different infestation levels and the degree to which each level influences the harvested crop (Stern,1973). The first step in obtaining this information is to establish an accurate, efficient sampling technique for use on a wide range of insects. Efficient and precise sampling is basic for the success of any integrated pest management programme (IPM). Different workers have studied on the population dynamics of different insects, Kretzschmar (1948) sampled soybean insects (in Minnesota, USA) by fumigation-cage and sweeping techniques and the species which were most abundant were underestimated by sweeping. Abraham *et al.* (1963) reported that sample unit size of 2'x 2' was most efficient for estimation of stem-borer infestation in rice. Boyer and Dumas (1963) described a method whereby insects were shaken from plants on to a cloth spread on the ground between rows. They indicated that this method was satisfactory for the various species, except for adults. The same method was used by Carner *et al.* (1974) for the survey of seasonal abundance of insect pests of soybean at Clemson, USA and find this method to be the most efficient in estimating numbers of most soybean insects became higher mean numbers with lower coefficients of variability were obtained. Hillhouse and Pitre (1974) utilized sweep-net method and Ground Cloth Shake method and compared sampling techniques to obtain measurements of insect population on soybean at Mississippi state, USA. They observed that the GCSM was the most efficient method for sampling of lepidopterous larvae and has a low relative variation and high fidelity to population changes but was time consuming.

Pedigo *et al.* (1972) compared fumigation-cage, sweep-net, Pitfall trap-shaking over a ground cloth and D-Vac as sampling procedures for green cloveworm, *Plathypena scabra* (F) in Lowa and reported that the fumigation-cage was the most precise technique but sweep-net gave greater relative net precision (based on precision and cost). Pitfall traps and D-Vac samples were the least precise for this species. The shake sample technique, utilizing a ground cloth, was not studied sufficiently for proper evaluation. Turnipseed (1974) opined that GCSM was the most efficient, based on numbers collected, coefficients of variability and time requirements. Sweeping across through 2 rows was adequate for most species and more efficient than sweeping along one row. Variations of the D-Vac method was generally ineffective for the insects sampled in their study. Population of cotton arthropods was estimated by Pieters (1978) using 30, 7-5,4 and 1-0 m row length and concluded that smaller sample size tended to have greater standard error at a fixed cost per sample unit size. Kaushik and Naresh (1984) while studying for estimation of larval population of *H. armigera* on two varieties of chickpea carried out at HAU, revealed that GCSM was most efficient, accurate and practical than VCM. Eight samples of 1.0 m row length per plot ($48m^2$) were sufficient to obtain 90 per cent accuracy in sampling.

2.2 Life-table studies

Ecological life-table is a concise summary of certain vital statistics of a population, whose members start life together. Such tables record a series of sequential measurements (Successive age intervals), the number of deaths, the remaining survivals, the rate of mortality and expectation of further life. The life-table also provides an important tool in the study of population dynamics of insects (the changes in the populations of insect-pests during different developmental stages throughout their life-cycle).

Life-tables were earlier used by actuaries for working out the expectancy of human beings of various ages for the purpose of life insurance. Subsequently, the concept of life-table was extended for studying the life expectancy of small animals such as rodents (Leslie and Ranson, 1940) birds (Park, 1948). However, Pearl and Parker (1921) were the earliest pioneer to make use of life-tables for studying the insect populations of *Drosophilla melanogaster* and *Tribolium confusum*. Later on, Leopold (1933), for the first time, realised the importance of life-tables for studying natural populations. This followed the publication of the first classical paper on the life-tables for natural populations of animals by Deevey (1947). In the late forties and early fifties, an attempt was made to construct a life-table based on laboratory cultures of insects (Birch, 1948) and 1953); Leslie and Park, 1949; Howe, 1953). Morris and Miller (1954) used this approach for describing the population dynamics of spruce budworm in the natural situation. The use of life-table based on a comparative study on survivorship curves for natural insect population was attempted by Ito (1959) in Japan, Slobodkin (1962); Morris (1963), Harcourt (1969), Odum (1971), Atwal and Singh (1974), Chu *et al.* (1976a,b), Singh *et al.* (1977) and Southwood (1978) made comprehensive use of life-tables for the study of natural population of insect pests while describing the population dynamics. Since early seventies, a plethora of informations has been accumulated on the insect-pests harbouring wide variety of hosts. To mention a few, Wilter *et al.* (1972) and Allen and Pienkowski (1975) were the ones who constructed the life-tables for the insect-pests of forests, orchard and few agricultural crops. Their efforts were followed by Atwal and Bains (1974) on *Trogoderma granarium* a pest of wheat var. Kalyan Sona, Atwal and Singh (1974) on *Chilo partellus*, on corn-borer, Chu *et al*, (1976a,b), Bilapate *et al.* (1979), Joshi (1981), Metcalf and Luckman (1982), Roy and Bains (1983), Rizvi (1988) and Veera Reddy and Bhatacharya (1988) on various food plants.

Age specific survival and fertility table of *Spilosoma obliqua* Walker was studied by Rizvi and Pathak (1998) on different food plants at different temperatures under controlled conditions. Various life parameters on these food plants revealed that castor was highly suitable for the population growth of *S. obliqua* followed by safflower, soybean, sugarbeet and mungbean.

Some attempts have been made in the past to formulate the semisynthetic diets of *Heliothis armigera* (Hubner) (Singh, 1977; Sharma and Sharaby, 1980; El-Gundy *et al.*, 1983; Wu, 1985). It has also been shown that the quality of the diet can be best judged by studying the life-table of insects. Tamaki *et al.*, 1972; Khazvatkw and Monaystyrkii, 1981). Reddy and Bhatnagar (1988) studied the life-table of *H. armigera* in semisynthetic diets. Gurs (1995) constructed age specific and stage specific life-table of *Antigastra catalaunalis* (Duponchel) on sesame.

Attempts were made to find out the extent of population buildup in the first and the following generations of various insect pests by use of trend index (I), generation survival fraction (S_G). The pioneers to discuss the stage specific life-table in a comprehensive manner were Atwal and Singh (1974), Roy and Bains (1983), Choudhary and Bhattacharya (1986), Sharma and Balla (1992) and Gurs (1995).

2.3 Survey of parasitoids

Today we know that most of the pests which play a detrimental role in the overall agricultural productivity scenario have their natural enemies. It has been observed that on a particular host plant when the population buildup of pest diminishes, the associated parasitoids or other natural enemies are found to be increased. In order to avoid excessive use of chemical measures, these parasitoids, if manipulated, may prove to be a potential source for suppressing the pest population. This necessiates a thorough overview of possible natural enemies of gram pod-borer. The literature on parasitoids of gram pod-borer has been subdivided here as under:

2.3.1 New Records of Parasitoids

Several scientists have recorded natural enemies of gram pod-borer. The earliest report of parasitoids of gram pod-borer was recorded by Hussain and Mathur (1924), wherein, *Microplitis* sp. (Braconidae) and *Atractodes* sp. (Ichneumonidae) find mention. Later on, Ayyar (1927) recorded *Tetrastichus* ayyari Rohwer as a new parasite. Other records in India included-*Chelonus* sp. (Braconidae) (Chopra, 1928); *Apanteles rufricrus*, Hal. and *Bracon (Microbracon) brevicornis* Wesm. (Braconidae) (Winsburn and Painter, 1932); *Chelonus narayani* Subba Rao. (Subba Rao, 1955); *Horogenes fenestralis* (Hlmgr.) (Tikar and Thakare, 1961); *Campoletis perdistinctus* Viereck (Gangrade, 1964) and *Banchopsis ruficornis* (Cameron) (Mathur, 1967). Manjunath *et al.* (1970) recorded *Trichogramma australicum G.* and *T. achaeae*, an egg parasitoid from India. Mathur (1970) mentioned four new records viz., *Euplectrus* sp. (External, gregarious, larval parasite), *Netelia* sp. (external, solitary, larval parasite), *Palexorista* sp. (internal, solitary, larval parasite) and *Agrypon nox* Morl. (internal, solitary, larval parasite). The other records were: *Carcelia illota* (Curr.), *Goniophthalamus halli*

(Mesnil), *Campoletis flavicincta* (Ashm.) and *Ecphoropsis perdistinctus* (Vier.) (Patel *et al.*, 1971); *Brachymeria lasus* (Walker) (Joseph *et al.* 1973); *Enicospillis biconatus* T. and *Palezorista* sp. the two larval parasites (Bilapate, 1981) and *Eucarcelia* sp. (Sithanantham, 1981). Divakar *et al.* (1983) reported *Parasieta* sp. as a new record from Karnataka. Singh and Balan (1986) recorded the braconids-*Apanteles* sp., *Bracon* sp. and *Microbracon hebetor*; the Ichneumonids Campoletis chloridae and Eulophid-*Euplectrus euplexia*, all larval parasitoids. *Hockeria apani* Doganlor was recorded from Turkey (Doganlar, 1990).

2.3.2 In India

The work done in India on the field of parasitzation by the parasitoids has been divided into the following sub heads:

2.3.2.1 Indigenous parasitoids

In India 25 Dipterous and 50 Hymenopterous parasitoids have been reported on this pest.

Tikar and Thakare (1961) stated that *Nythobia 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 hyper parasitization at Nagpur. According to Gangrade (1964), the parasitization by *Campoletis perdistinctus* was to the extent of 34.5 per cent on gram 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.* (1968) reared two egg parasitoids, viz. *T. australicum* Girault and *T. achaeae* Nagaraja and Nagarkatti and a Scelionid - *Telenomus* sp. and inferred that parasitism by *Trichogramma* spp. ranged from 2-80 per cent. Rao (1968) observed that *Banchopsis ruficornis* (Cam.) (being a solitary larval parasite) caused 10 per cent parasitism in the field, but its utility for augmentative release is limited due to univoltine nature and also mentioned the per cent parasitization by *Ecphoropsis perdistinctus* Vier., *Encospilus* sp., *Eriborus* sp., *Palexorista imberbis* (Wied), *Eucarcelia illota* Curr., *Goniophillus halli* Mesnil and *Drino imberbis* Wield. Under the agroclimatic conditions of Gujarat, the parasitization by *Carcelia illota* Curran, *Ecphorophsis peridistinctus* Vier and *Goniophthalamus halli* Mesnil was reported by Patel *et al* (1971). Field parasitism by egg parasites, *Trichogramma* spp. were found to be high, 80 per cent on tomatoes and cowpea crops, 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 (Bhatanagar and Davies, 1978). Later on, Bhatnagar (1981) also seconded the findings by recording the high degree of mortality to eggs and larvae of this pest by *Trichogramma* spp. The per cent 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 reaches to maximum in the months of January (in case of early sown crop) and in February (in case of late sown crop) (Deka *et al.*, 1987). Parasitism due to *Eriborus* sp.

was 43.7 per cent 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.). *B. gelechiae* (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). Highest parasitism by *Eriborus argenteopilosus* (Cameron) was also confirmed by Bilapate *et al.* (1988). Several parasitoids of the pest on sorghum were observed by Pawar *et al.* (1989), viz., Hymenoptera: *Trichogramma chilonis* Ishii., *Trichogrammatoidea bactrae, T. fumats* Nagaraja (egg parasitoids), *Apanteles* sp., *Campoletis chloridae* Uchida, *Disophrys* sp., *Eriborus argenteopilosus* Cameron., *Eriborus trochanteratus* Morley, *Tenelucha* sp. (larval parasitoids) and Diptera: *Carcelia illota* Curran, *Exorista xanthaspis* Wied., *Goniophthalamus halli* Mes., *Palexorista laxa* Curran and *Sturmiopsis inferens* Tns. sixteen species of natural enemies belonging to the Trichogrammatidae, Braconidae and Ichneumonidae were recorded by Srinivas and Jayaraj (1989), who observed that *Dadegma fenestralis* collected from Ist to 3rd 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. Percentage parasitization was observed by Sivaprakasam (1997) on *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), *Palexorista laxa* (50 in irrigated), Eriborus sp. (10.5 in rainfed) and *Bracon* sp. (7.8 in rainfed).

Singh (1988) opined that the following measures may be adopted for tackling the immediate problem by inundative release of *Trichogramma chilonis* @ 2,00,000 adults/ha at weekly interval during the egg-laying period of this pest.

Gupta *et al.* (1997) reared parasitoids from pod-borer in mid hills of Himachal Pradesh viz., *Trichogramma australicum* Girault (*T. chilonis* Ishii) and *T. achaeae* 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 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. Mattoo (1998) recorded parasitization from Jammu by *Tetrastichus ayyari* Rohwer (Hym., Eulophidae) and *Brachymeria lasus* (Walker) (Hym. Chalcididae) at the late stage of chickpea crop.

2.3.2.1.1 *Campoletis chloridae* Uchida (Hym., Ichneumonidae)

Out of 80 parasitic natural enemies recorded in India, so far, 50 belongs to the parasitic Hymenoptera and among them *Campoletis chloridae* 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 stages. Significant role on early instar larvae irrespective of sowing dates was reported as a potential parasitoid infesting chickpea and other pulses (Gangrade, 1964; Mehto *et al.*, 1986; Pawar *et al.*, 1989;

Nikam and Gaikwad, 1989). 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, 7-9 and 13-15 days, respectively; the feeding activity of the larva was reduced after parasitization and after the emergence of the parasite, the host larva dies (Chari *et al.* 1988). In the findings of Yadav and Patel (1981), the percentage parasitism by *C. chloridae* initially occurred in the second week of September and reached to maximum during the 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 (Yadava *et al.* 1985). Higher parasitization was reported in December at Kanpur from February to March in Haryana (Singh and Singh, 1986). However, the parasite is widely distributed from Himalayang to Cape commerin and the per cent parasitism ranged from 1.43-1.33 (Srinivas, 1987). High degree of mortality to the pod-borer 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 inferred that it sometimes exceeds 35 or even 33 per cent. In Uttar Pradesh, parasitism was recorded from 3rd week of April, 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 (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 this finding, it could safely be presumed that this parasitoid will not be effective one because it is a host of hyperparasitoids-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 parasitization of 43.9 per cent was recorded in the first fortnight of December and lowest of 12 per cent during the last week of January in Tamil Nadu by Srinivas and Jayaraj (1989). Nikam and Gaikward (1991) studied the rate of parasitization from first instar to last instar larval stages in laboratory and recorded the maximum parasitization 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. The information based on the data collected from Jammu by Mattoo (1998) revealed that this parasitoid made its presence felt throughout the cropping season of chickpea.

2.3.2.2 Exotic parasitoids

Commonwealth institute of Biological Control imported 5 parasitoids viz., *Eucelatoria bryani* (s), *Cotesia marqiniventris* (C.), *Campoletis flavicincta* (Ashm.), *Cotesia kazak* (T.) and *Hyposoter* *didymator* (Thbs.), out of this the tachinid - *E. bryani* preferred 4th and 5th instar stage of gram pod-borer (Mani and Nagarkatti, 1981). Following parasitoids were introduced in India since 1969 to test them against this pest on many crops: *Trichogramma brasiliensis* (Ashm.) (South America), *T. perkinsi* Girault (USA), *T. pretiosum* Riley (Mexico and USA), *Chelonus blackburni* (Cameron, Arizona), *C. insularis* (West Indies), *Microplitis croceipes* Cresson, *Cotesia marqiniventris* (Cresson.) (Arizona), *C. Kazak* Telenga (Greece), *Campoletis flavicincta* (Ashm.) (Trinidad), *Hyposoter didymator* (Thunberg) (Greece), *Lespesia archippivora*, (Riley) and *Eucelatoria* bryani Sabrosky (Arizona) (Krishnamurthy and Mani, 1988). For tackling gram pod-borer 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 America have been introduced and evaluated from time to time. Among these parasitoids, *T. brasiliensis* has been recorded on tomato in Karnataka (Parasitizing 34.6 to 51.3 per cent eggs of the pest), *B. kirkpatricki* from tomato eco-system in Karnataka and from cotton eco-system in Maharashtra and Gujarat, *C. blackburni* recorded from N. India, *E. bryani* from tomato eco-system in Karnataka (parasitizing upto 8 per cent larvae), the parasite has already established in Eastern UP and Hydrabad. *H. didymator* which is an Eastern parasitoid in Russia, Bulgaria, Turkey, Syria, Israel, Spain, Morocco and many other countries, have been introduced in our country (Singh, 1988).

The extent of parasitization by *C. blackburni*, an egg parasite in the cotton fields was 3.77 per cent (Sarkate *et al.* 1978) and 37.8 per cent (Rao *et al.* 1979) *Eucelatoria* sp. *H. armigera* was introduced from USA and reared for the field releases (Sankaran and Nagaraja, 1979). Out of the few parasitoids released, *C. marqiniventris* failed to establish while *C. flavicincta* could not be colonized 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 (00 to 16.66 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 noticed by Prasad *et al.* (1982), after releasing the egg-larval parasite, *C. blackburni*. Mani and Krishnamurthy (1983) observed 34.6 to 51.3 per cent parasitization in tomato when released in the field. *Telenomus remus* Nixon, an egg parasitoid originating from New Guinea, can serve as alternate host of gram pod-borer (Joshi *et al.*, 1984).

Inundative releases of *T. brasilensis* and *T. pretiosum* @ 2,50,000 adults/ha resulted in 16.67 to 62.94 per cent and 20.00 to 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 form USA, attacked early instar larvae (3-5 days old) and parasitization ranged from 20-30 per cent (Chari, 1987), however, the recovery of *E. bryani* was found to vary with the crop (Sithanantham, 1987).

2.3.2.3 Field release of more than one parasitoid

The combined effect of parasitization by *D. fenestralis* and *B. ruficornis* (both ichneumonids) was about 63.33 per cent as the results shown by the experiment on chickpea conducted by Singh *et al.* (1983). Inoculative studies have been done by some scientists by using more than one parasitoid *T. chilonis*, *T. pretiosum*, *B. hebetor*, *B. kirkpatriki* (Wilkinson), *C. blackburni* and *E. bryani* resulted in 92.4 per cent reduction of pest in tomato and inundative release of *T. chilonis* reduced the pest population when large number of *B. hebetor* were released.

2.3.3 In other countries

The list of natural enemies recorded throughout the distribution range of *H. armigera* is quite long, 95 have been recorded in Uzbekistan, 40 in Krasnadar, 22 in Turkmenia and 32 in Azerbiajan. In Azerbiajan Republic, in 1964; *Bracon hebetor* alone parasitized 15-70 per cent of the caterpillars (70 per cent parasitism was observed in September after the chemical sprays were 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. simonovi* alone caused 45.8 per cent parasitism in cotton fields. In Tadjikistan, *Cotesia kazak* caused 5-12 per cent parasitism in the beginning of the season, but in the third generation, the percentage parasitism reached 50-70. *B. 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 per cent control, highest being 80 per cent. The best period for release 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 per cent caterpillars in cotton growing areas of southern Kazakhistan. A combination of *Trichogramma* spp. and *B. hebetor* was used in Russia for combating the pest. In North Syria, the principal parasitoids were *Meteorus* sp. and *B. hebetor*. In South Africa 19 parsitoids 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 (Kovalenkov 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, fifth and sixth instar larvae were parasitized by *Habrobracon brevicornis* (*Bracon brevicornis*) (47.6 and 38.8 per cent) and *Hockeria ufraiensis*, a pupal parasitoid (33.0, 56.0 and 80.0 per cent).

By the studies of Murray and Rynne (1994) in the green house experiment forecasted that the level of parasitism would enhance during the first spring generation of gram pod-borer. In Iran, Noori (1994) revealed that the activity of *Habrobracon hebetor* began in early June and lasted till mid-September and the rate of parasitism increase with the increase of temperature. The prasitism occurred in the early sown than in the late sown crops. In the green house studies conducted by Murray *et al.* (1995), in Australia, investigated the rate of parasitism by *Hyposoter didymator* and *Cotesia kazak* and found lowest on chickpea as compared to sorghum, sunflower, etc.

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MATERIALS AND METHODS

3. MATERIALS AND METHODS

The present investigation was carried out during rabi, 1998-99 at the Dryland Agricultural Research Station, Dhiansar, Jammu. The experiments were laid out under rain-fed field conditions and the rearing of gram pod-borer of chickpea for the collection of parasitoids was done at the Regional Agricultural Research Station, SKUAST at RARS, R.S.Pura, Jammu.

Rakh Dhiansar is located at a distance of about 18 km East of Jammu city near the Bari-Brahmana Railway Station on the Jammu-Pathankot National Highway and lies at a latitude of 32° 39' North and a longitude 74° 54' East at an elevation of 332 metres above the sea level. The experimental site represents the typical kandi belt of Jammu.

The climate of kandi-belt is of subtropical type with three well defined seasons, namely winter, summer and monsoon. The winter crop starts from November and continues up to 15th April. The second half of December and January are usually the coldest periods when the day's minimum temperature varies between 3-6°C.

The soils of the Dryland Research Station at Dhiansar are alluvial ranging from sandy loam to loamy sand. The slope ranges from 1-2 per cent North East to South. The soils are well drained, light textured, coupled with poor organic content resulting in the poor water holding capacity of the soils. The pH ranges between 7.1 to 7.8.

The present investigations were carried out under the subheads:

3.1 ESTIMATION OF POPULATION

For the study of estimation of population of gram pod-borer on chickpea, a trial was laid out during rabi 1998-99 at Dryland Agricultural Research Station of SKUAST, Dhiansar, Jammu. Healthy and certified seeds of two varieties of chickpea namely, C-235 (timely sown var.) and Gourav (late sown var.) were obtained from the Regional Agricultural Research Station at Samba and plants of both varieties were raised in two separate plots. Main plots were divided into ten subplots of 4x4 metre size. The crop was sown on 15th October, 1998 in case of timely sown var. (C-235) and on Ist November, 98 in case of late sown var. (Gourav) in a well ploughed, prepared and levelled seed beds. All the agronomical and other cultural practices followed the recommended 'package and practices' for chickpea crop issued by the SKUAST, Srinagar/Jammu. Each sub plot was divided into three unit sizes of row length viz., 0.5, 1.0 and 1.5 m length. For sample selection purpose and to determine the efficiency and accuracy of sampling observations were taken on three sample unit sizes, randomly in each subplot and replicated twice. The observations were taken weekly through to the harvest of the crop. Two different methods were followed for the estimation of population, namely, Visual Count Method (VCM) and Ground Cloth-Shake Method (GCSM). The time required during each observation were recorded by carefully counting them visually on the plant in the rows of different sample unit sizes in VCM and in GCSM, a white cloth sheet (1x0.5 m) was stretched in between two rows and plants were briskly shaken to dislodge the larvae on to the sheet. The number of larvae available on the sheet were counted and thereafter released on the same plant. Observations from each unit of different unit sizes and replicated twice randomly were taken every week and the time taken during each observation was recorded. Comparision of VCM with GCSM was done on the basis of mean number of larvae converted into per 1 m^2 in both the varieties. Student 't' test was used to compare population means and two-way analysis of variance (Snedecor and Cochran, 1967). Relative variation (RV), Time (man hr.) taken per sample and Relative Net Precision (RNP) values for two methods were compared to determine the efficiency and accuracy of sampling. RV and RNP were calculated by the following formulae:

$$RV = \frac{\text{SE (Standard Error)}}{\text{X (Mean number of larvae/sample)}}$$

$$RNP = \frac{1}{\text{RV X Time (man hr) taken/sample}}$$

Lower the RV and higher RNP values, more accurate and efficient that method would be.

Three different sample unit sizes of row length (0.5m, 1.0 and 1.5 m) using GCSM were compared by calculating the mean, standard error and RV values.

From the statistical analysis it was concluded that which method and sample unit size is most practical, efficient, economical and resonably accurate for estimation of larval population of gram pod-borer on chickpea.

3.2 LIFE-TABLE STUDIES (STAGE SPECIFIC)

Life table studies of gram pod-borer were carried out under natural conditions. Eggs laid by gravid female were allowed to hatch under natural conditions. The larvae thus hatched were distributed singly to the plants with the help of camel hair brush. The stage specific (Harcourt, 1969; Southwood, 1978) life-table was constructed.

Gravid female moths trapped in the late hours of the evening during field inspection were caged using nylon-mesh, over the young shoots/seedlings which were bereft of all other leaves and buds except 2-3 fresh leaves at the top. A cotton swap dipped in 30% sugarated water was tied inside the nylon-mesh cage as food for the moth.

Of the newly laid eggs, a cohort of 100 eggs was allowed to hatch on/under the same leaves after shifting the female alongwith cage to next plant. Hatching was recorded daily. As the hatching started, the 1st instar larvae were picked up continuously and distributed over other fresh shoots. The larval mortality was observed daily until these were fully fed. Finally the fully fed larvae were allowed to pupate. Pupae thus collected were caged individually and like the larval stage, observations on pupal mortality, if any, were also recorded daily till the emergence of the adults. The adults so obtained, were sugar-fed continually till their death so as to record the data on the life-span. Ratio of male to female were counted and one pair each were caged separately for mating and finally the gravid female was again caged on the plant for next generation. This process goes on till the harvest of the crop.

All the calculations were made on the assumption that eggs mortality occurred either:

1. Due to unfertilized eggs or death of the embryo
2. Or due to the parasitization/predation

Unhatched eggs were counted immediately after the hatching period was over.

The table was constructed on the basis of the data so obtained. First three instars were considered as early and rest instars as late instar larvae.

Following standard heads were used to compute stage specific life-table.

X = stage of the insect

lx = number surviving at the beginning of the stage x

dx = mortality during the stage indicated in the column x

100 qx = apparent mortality or percentage mortality at the beginning of the stage indicated in the column x

sx = survival rate within x

Accordingly, the data so obtained were used to compute the following life parameters

3.2.1 Apparent mortality

This is the measured mortality in terms of percentage that enters that stage. It was calculated by using the formula:

$$\text{Apparent mortality} = \frac{dx}{lx} \times 100$$

3.2.2 Stage specific survival fractions (sx)

Data on apparent mortality were used for calculating this parameter of each stage with the equation:

$$S\,x \text{ of particular stage} = \frac{lx \text{ of subsequent stage}}{lx \text{ of particular stage}}$$

3.2.3 Generation survival fraction (S_G)

This parameter was calculated using the equation

S_G = $SE(SL_1+SL_2).\ SP$, where

SE = Sx of egg stage

SL_1 = Sx of early instar stage

SL_2 = Sx of late instar stage and

SP = Sx of pupal stage

3.2.4 Real mortality (RM)

Population density at the beginning of each stage was taken as the basis for calculating real mortality by the formula given hereunder:

$$RM = 100 \times \frac{di}{LC}$$

where: di = death in the stage

LC = size of the cohart at the beginning of the generation

3.2.5 Mortality survival ratio (M.S.R.)

It is defined as the increase in population that would have occurred if the mortality in the stage in question had not occurred and was calculated as follows:

$$\text{M.S.R. of a particular stage} = \frac{\text{Mortality in particular stage}}{\text{Lx of the subsequent stage}}$$

3.2.6 Indispensable mortality (I.M.)

This type of mortality would not be there in case the factor(s) causing it are not allowed to operate. However, the subsequent mortality factors operate and calculated by multiplying the number of adults emerged by M.S.R. of a particular stage. The formula reads as

I.M. = No. of adults emerged X M.S.R. of a particular stage

3.2.7 K-values

It is the key-factor which is mainly responsible for increase or decrease in number from one generation to another and was calculated as the difference between the successive values for log lx. By adding the K-values of different developmental stages of the insect, total generation mortality indicated by K was obtained.

$K = k_0+k_1+k_2+k_3+k_4$ where k_0, k_1, k_2, k_3 and k_4 are the k-values at egg, early instar larval, late instar larval and pupal stages, respectively.

3.2.8 Trend index and generation survival

From the data available on stage specific life-tables, trend index (I) and generation survival (SG) values were calculated in order to have an idea whether:

i) the existing mortality factors were responsible to bring about mortality to any extent or not i.e.

I value > unity —> Mortality factors had less or no effect

I value < unity —> mortality factors had pronounced effect

ii) further, if the trend index value (I) was more than unity or less than unity what would be the carry over number of adults in the next generation

iii) in addition to the above, the higher/lower values of (SG) would be an indicator in support of (I) values.

The formula used, was as follows:

Trend index (I) = N_2/N_1

Generation survival (SG) = N_3/N_g where

N_1 =the number of larval population in the previous generation

N_2 = actual number of early instar larvae in the current generation

N_3 = number of the females x 2 of the current generation

3.3 SURVEY OF THE PARASITOIDS

Collection of the parasitoids associated with the gram pod-borer were made during rabi 1998-99. In order to search for parasitoids, a regular monitoring was conducted during the growing period of the crop, right from the seedling stage till the harvest. The eggs, larvae and pupae of gram pod-borer were collected from different agricultural farms within the vicinity of the experimental site. These were later reared individually in the glass tubes covered with muslin cloth and tied with rubber band. The fresh leaves were provided as food for the larvae and pods in the later stages of the crop. Parasitoids emerged at larval/pupal stages were collected and preserved in 70 per cent ethyl alcohol and were sent to Division of Entomology, IARI, New Delhi for identification.

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EXPERIMENTAL FINDINGS

4. EXPERIMENTAL FINDINGS

4.1 ESTIMATION OF POPULATION

In order to estimate the population of gram pod-borer on chickpea crop, a trial was laid out at Dhiansar, Jammu, and data was recorded randomly by weekly observation on two varieties namely, C-235 (Timely sown) and Gourav (Late sown). Sample unit sizes were of different row lengths i.e 0.5, 1.0 and 1.5 m length and replicated twice. The duration of time taken during each observation were also noted. Two different methods of observations were followed viz., Ground cloth-shake and Visual Count Method (VCM). The inferences drawn about various parameters under study, mentioned in the following sub-stations as regard to estimation of population, are based on the statistical analyses, that is, using analysis of variance (ANOVA) technique and student's t-test (ANOVA tables are given in the appendix II).

4.1.1 Mean population values by GCSM and VCM (Table 1-2)

The data obtained by the observation during the cropping season, which was spread over 19 weeks, i.e 29th Nov., 98 to 10th April, 1999, revealed that the population count obtained in both the varieties by GCSM were significantly greater ($P < 0.05$) than the VCM. On an average 5.653 and 5.480 larvae per m^2 by GCSM, whereas, 4.938 and 4.638 larvae per m^2 by VCM in C-235 and Gourav varieties respectively were counted.

Table-1.Mean population values per m^2 for *H. armigera* on timely sown variety of chickpea by GCSM and VCM at Rakh Dhiansar, Jammu during rabi 1998-99.

Week	Date	Timely sown var.(C-235) GCSM	VCM
1.	Nov.29- 5 Dec.,98	4.478 (1.979)^{abcde}	3.625 (1.908)^{cdef}
2.	6-12	5.757 (2.312)^{defgh}	5.180 (2.229)^{efgh}
3.	13-19	6.752 (2.669)^{hi}	5:970 (2.511)^{fghi}
4.	20-26	3.981 (1.974)^{abcd}	2.772 (1.585)^{abcd}
5.	Dec.27-2 Jan.,99	4.265 (2.073)^{bcdefg}	3.696 (1.884)^{bcde}
6.	3-9	2.559 (1.598)^{ab}	1.990 (1.349)^{ab}
7.	10-16	2.559 (1.598)^{ab}	1.208 (1.139)^{a}
8.	17-23	2.417 (1.537)^{a}	1.990 (1.409)^{abc}
9.	24-30	6.184 (2.524)^{fghij}	5.476 (2.381)^{efghi}
10.	Jan.31-6 Feb	4.096 (2.28)^{cdefgh}	4.194 (2.063)^{defg}
11.	7-13	6.610 (2.477)^{efghij}	5.828 (2.447)^{efghij}
12.	14-20	7.579 (2.740)^{hi}	6.604 (2.642)^{fghi}
13.	21-27	8.032 (2.876)^{hi}	7.250 (2.651)^{ghi}
14.	Feb.28-6 Mar.	6.611 (2.613)^{hij}	5.229 (2.411)^{fghi}
15.	7-13	6.468 (2.574)^{ghij}	5.331 (2.334)^{efghi}
16.	14-20	7.890 (2.837)^{hi}	7.108 (2.717)^{hi}
17.	21-27	7.464 (2.778)^{hi}	6.682 (2.583)^{fghi}
18.	Mar.28-3 Apr.	9.952 (3.159)^{r}	8.815 (2.851)^{i}
19.	4-10	3.128 (1.787)^{abc}	2.559 (1.598)^{abcd}
CD ($P<0.05$)		0.501	0.486

- Figures given in parentheses are transformed values ($\sqrt{x+0.5}$)
- Figures with the same letter (superscript) are statistically at par

Table- 2. Mean population values per m^2 for *H. armigera* on Late sown variety of chickpea by GCSM and VCM at Rakh Dhiansar, Jammu during rabi, 1998-99.

Week	Date	Late sown var. (Gourav) GCSM	VCM
1.	Nov.29-5 Dec.,98	4.904 (2.234)^{de}	3.980 (2.016)^{bcd}
2.	6-12	5.400 (2.256)^{de}	3.888 (2.123)^{de}
3.	13-19	6.615 (2.566)^{efg}	5.616 (2.558)^{defg}
4.	20-26	3.270 (1.758)^{cd}	2.559 (1.598)^{abc}
5.	Dec.27-2 Jan.,99	2.203 (1.487)^{abc}	2.061 (1.316)^{ab}
6.	3-9	1.919 (1.388)^{abc}	1.350 (1.200)^{ab}
7.	10-16	1.564 (1.247)^{a}	0.995 (1.057)^{a}
8.	17-23	1.919 (1.388)^{abc}	1.350 (1.200)^{ab}
9.	24-30	6.611 (2.598)^{efg}	5.402 (2.320)^{cde}
10.	Jan.31-6 Feb.	6.113 (2.477)^{def}	4.904 (2.149)^{cde}
11.	7-13	7.180 (2.664)^{efgj}	6.326 (2.559)^{ghijk}
12.	14-20	6.753 (2.596)^{efg}	5.900 (2.491)^{def}
13.	21-27	7.606 (2.753)^{efg}	6.823 (2.619)^{hijk}
14.	Feb.28-6 Mar.	5.473 (2.332)^{de}	4.558 (2.219)^{cde}
15.	7-13	6.966 (2.678)^{efg}	6.184 (2.545)^{defg}
16.	14-20	8.460 (2.814)^{gh}	7.251 (2.724)^{jk}
17.	21-27	7.820 (2.774)^{fgh}	7.038 (2.671)^{ghijk}
18.	Mar.28-3 Apr.	9.810 (3.162)^{h}	9.028 (3.031)^{k}
19.	4-10	3.553 (1.733)^{bc}	2.771 (1.660)^{bc}
CD ($P<0.05$)		0.482	0.393

- Figures given in parentheses are transformed values ($\sqrt{x+0.5}$)
- Figures with the same letter (superscript) are statistically at par

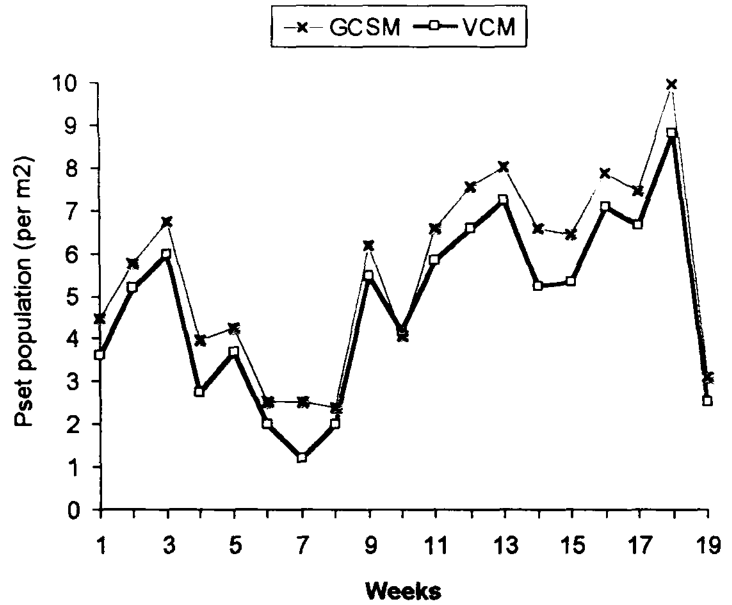

Fig.1. Comparison of two sampling techniques (GCSM and VCM) for estimation of population of *H. armigera* on chickpea (C-235 var.)

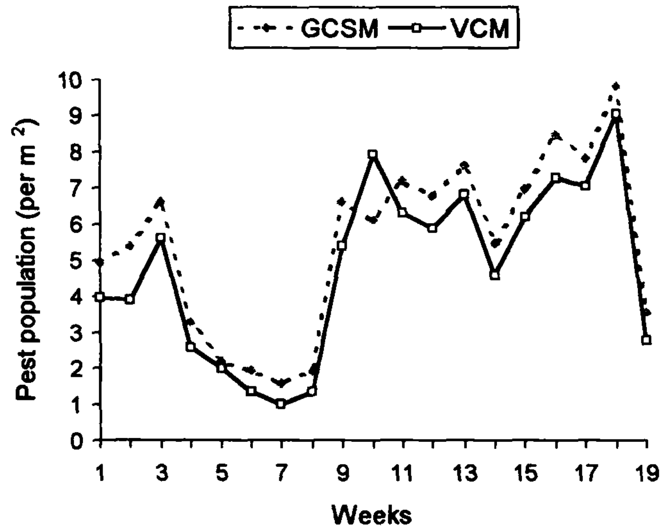

Fig.2. Comparison of two sampling techniques (GCSM and VCM) for estimation of population of *H. armigera* on chickpea (Gourav var.)

4.1.2 Relative net precision values (RNP) by GCSM (Table-3)

Relative net precision values obtained for the estimation of larval population of gram pod-borer by GCSM, by comparing the three sample unit sizes viz., 0.5, 1.0 and 1.5 m row length in both the varieties (C-235 and Gourav), it was found that the RNP values obtained by 1.0m row length were greater values than the unit sizes of 0.5m and 1.5m. In almost all the observations taken throughout the cropping season in both the varieties, the average RNP values of 1.0m row length was 2.983 whereas, the values were 1.772 and 2.400 in case of 0.5 and 1.5m row length in case of timely sown crop. The same trend was followed in the late sown variety where RNP of 0.5, 1.0 and 1.5m row length were 1.218, 2.687 and 1.262 respectively.

4.1.3 Sample unit size (Table 4)

Data given in table 4 suggested that when comparison was made on the population count by GCSM and VCM on different unit sizes in both the varieties, the population count on sample unit size of 0.5 m row length was found to be more biased and overestimated. On the other hand, the population count on the sample unit size of 1.5 m row length happened to be biased and underestimated. However, in the sample unit size of 1.0 m row length the population count lying in between the count of aforesaid unit sizes, seems to be more precise because, the corresponding RNP values were comparatively more, hence in this case the estimated value of population buildup will be near to actual count as it would be.

Table-3. Relative Net Precision (RNP) values of three sample unit sizes for two varieties using GCSM for *H. armigera* on chickpea.

Week	Date	Row length (m) of Var. C-235			Row length (m) of Var. Gourav		
		0.5	1.0	1.5	0.5	1.0	1.5
1.	Nov.29-5 Dec.,98	0.828	0.894	2.876	1.53	3.91	1.53
2.	6-12	0.677	4.504	1.611	1.21	1.55	1.31
3.	13-19	1.790	4.095	4.625	2.17	3.91	1.53
4.	20-26	1.250	4.095	1.739	1.33	1.73	1.31
5.	Dec.27-2 Jan.,99	1.176	4.504	2.619	0.48	1.02	1.21
6.	3-9	0.765	1.904	1.068	0.48	1.02	0.94
7.	10-16	0.742	1.818	0.068	0.49	0.68	0.64
8.	17-23	0.765	1.818	0.711	0.46	1.02	0.64
9.	24-30	1.642	3.336	3.336	1.55	3.46	3.33
10.	Jan. 31-6 Feb	0.975	3.603	2.436	1.49	2.51	1.35
11.	7-13	1.400	3.831	3.595	2.19	3.46	1.35
12.	14-20	1.336	3.968	3.940	1.55	3.46	1.35
13.	21-27	1.958	3.968	3.668	1.55	3.79	1.26
14.	Feb.28-6 Mar.	1.277	3.968	3.465	0.75	3.21	1.26
15.	7-13	0.762	3.106	2.689	1.43	3.50	1.26
16.	14-20	0.909	2.513	2.481	0.74	4.96	1.26
17.	21-27	1.307	3.584	2.580	1.95	2.66	1.26
18.	Mar.28-3 Apr.	1.922	4.117	2.580	1.37	4.60	2.64
19.	4-10	0.800	1.176	1.538	0.32	0.61	0.46
	Average	1.172	2.983	2.40	1.218	2.687	1.362

Table-4. Estimation of population of *H. armigera* on two varieties of chickpea through two sampling techniques in different unit sizes

Unit size(m)	** Population count per m^2 by GCSM		Population count per m^2 by VCM	
	C-235	Gourav	C-235	Gourav
0.5	7.612 (2.670)*	7.477 (2.603)	6.063 (2.322)	5.861 (2.269)
1.0	5.520 (2.374)	5.490 (2.307)	5.253 (2.287)	5.004 (2.243)
1.5	3.829 (1.956)	3.475 (1.864)	3.228 (1.816)	3.049 (1.811)
CD ($P<0.05$)	0.199	0.191	0.193	0.156

* Figures given in parenthesis are transformed values $\sqrt{x+0.5}$

** Mean count through the harvest of crop

4.1.4 Comparison of GCSM with VCM (Table 5 and Figs. 1-2)

The data given in Table-5 and Figs. 1-2 revealed that the relative variation (RV%), Time (man hr) taken during per sample and Relative Net Precision (RNP) values obtained by the observations taken on both the varieties (Timely sown and late sown) by GCSM and VCM were compared to determine the accuracy and efficiency of the sampling. On an average of all the observations taken during the cropping season (19 weeks), in both the varieties. The RV% values were found to be more in case of VCM than GCSM and reverse trend happened in case of RNP values in both the varieties. The RV% values when calculated were found to be 39.71% in case of C-235 and 9.8% in case of Gourav (more values in VCM than GCSM) and RNP values 32.70% (C-235) and 8.73% (Gourav var) more in GCSM than VCM. As far as the time (man hr.) taken during each observation (per sample) was concerned, it was found that more time was taken in case of VCM than GCSM. On average of all the observation about 13. 76% more time was spent when the observations were taken by VCM in case of Gourav var. and 24.14% more time in case of C-235.

4.2 LIFE-TABLE STUDIES (STAGE SPECIFIC)

In order to find out the key factors responsible for population dynamics of gram pod-borer (the fluctuation in the population in different generations occurring in the same season of the crop), the data pertaining to various parameters were recorded and presented in the tables.

Table-5. Relative variation, time and relative net precision values to compare two sampling techniques for *H. armigera* larvae on two varieties of chickpea

Variety	Ground Cloth-Shake Method			Visual Count Method		
	Relative variation (RV%)	Time (man hr) per sample	Relative net precision (1/RV%xTime)	Relative variation (RV%)	Time (man hr.) per sample	Relative net precision (1/RV%xTime)
C-235	20.701	0.0290	2.185	28.824	0.036	1.590
Gourav	27.778	0.0297	1.755	30.448	0.033	1.614

It is worth mentioning here that in all four stages specific life-tables have been prepared separately, one each for the four successive generations observed during Nov., 1998 to April, 1999. Although, there were some overlapping, the four broods considered were distinct from each other. The span covered by each generation during the present study was as follow.

First generation - 1st November, 1998 to 16th December, 1998

Second generation- 17th December, 1998 to 26th January, 1999

Third generation- 27th January 1999 to 12th March, 1999

Fourth generation- 13th March 1999 to 12th April, 1999

The stage specific life-table for all the four generations are presented in tables (6,7,8,9). The stage specific life-table will be dealt under the following heads:

a- Apparent mortality

b- Survival fraction

c- Real mortality

d- Mortality- survival ratio

e- Indispensable mortality

f- K-values

g- Trend index and generation survival

Further, for sake of convenience, the observations will be dealt in a comparable manner for all the four generations.

Table-6. Stage specific life-table of *H. armigera* on chickpea.

Generation-I [Ist Nov., 98 to 16th Dec., 98]

Stage (x)	No surviving at the beginning of the stage (lx)	No. dying in each stage (dx)	Mortality factors (dxf)	Apparent mortality (100qx)	Survival fraction (sx)	Real mortality (100rx)	Mortality survival ratio of stage (M.S.R.)	Indispensable mortality (I.M.)	Log lx	k-value
Egg	100	17	1,2,3	17.00	0.83	17	0.204	8.364	2.000	0.081
Early instar larva	83	19	1,2,5,7	22.89	0.77	19	0.297	12.177	1.919	0.113
Late instar larva	64	12	1,2,4,6	18.75	0.81	12	0.231	9.471	1.806	0.090
Pupa	52	11	1,2	21.15	0.79	11	0.267	10.947	1.716	0.104
Adult	41	-	1,2						1.612	

1 = Temperature 2 = Relative humidity 3 = Sterile eggs 4 = Parasites K=0.388

5 = Predators 6 = Inability to enclose 7 = Unknown factors

Table-7. Stage specific life-table of *H. armigera* on chickpea.

Generation-II [17th Dec., 98 to 26th Jan., 99]

Stage (x)	No surviving at the beginning of the stage (lx)	No. dying in each stage (dx)	Mortality factors (dxf)	Apparent mortality (100qx)	Survival fraction (sx)	Real mortality (100rx)	Mortality survival ratio of stage (M.S.R.)	Indispensable mortality (I.M.)	Log lx	k-value
Egg	100	22	1,2,3	22.00	0.78	22	0.282	10.434	2.000	0.108
Early instar larva	78	14	1,2,5,7	17.94	0.82	14	0.218	8.066	1.892	0.086
Late instar larva	64	10	1,2,4,6	15.62	0.84	10	0.185	6.845	1.806	0.074
Pupa	54	17	1,2	31.48	0.68	17	0.462	17.094	1.732	0.164
Adult	37	-	1,2						1.568	

1 = Temperature 2 = Relative humidity 3 = Sterile eggs 4 = Parasites K=0.432

5 = Predators 6 = Inability to enclose 7 = Unknown factors

Table 8. Stage specific life-table of *H. armigera* on chickpea

Generation-III [27th January, 99 to 12th March, 99]

Stage (x)	No.surviving at the beginning of the stage (lx)	No. dying in each stage (dx)	Mortality factors (dxf)	Apparent mortality (100qx)	Survival fraction (sx)	Real mortality (100rx)	Mortality survival ratio of stage (M.S.R.)	Indispensable mortality (I.M.)	Log lx	k-value
Egg	100	25	1,2,3	25.00	0.75	25	0.333	12.987	2.000	0.125
Early instar larva	75	9	1,2,5,7	12.00	0.88	9	0.136	5.304	1.875	0.069
Late instar larva	64	14	1,2,4,6	21.87	0.78	14	0.280	10.92	1.806	0.108
Pupa	50	11	1,2	22.00	0.78	11	0.282	11.00	1.698	0.107
Adult	39	-	1,2						1.591	

1 = Temperature 2 = Relative humidity 3 = Sterile eggs 4= Parasites K= 0.409
5 = Predators 6 = Inability to enclose 7 = Unknown factors

Table 9. Stage specific life-table of *H. armigera* on chickpea

Generation-IV [13th March, 99 to 12th April, 99]

Stage (x)	No.surviving at the beginning of the stage (lx)	No. dying in each stage (dx)	Mortality factors (dxf)	Apparent mortality (100qx)	Survival fraction (sx)	Real mortality (100rx)	Mortality survival ratio of stage (M.S.R.)	Indispensable mortality (I.M.)	Log lx	k-value
Egg	100	19	1,2,3	19.00	0.81	19	0.234	10.062	2.000	0.092
Early instar larva	81	12	1,2,5,7	14.81	0.85	12	0.174	7.482	1.908	0.070
Late instar larva	69	7	1,2,4,6	10.14	0.90	7	0.112	4.816	1.838	0.046
Pupa	62	19	1,2	30.64	0.69	19	0.444	19.092	1.792	0.159
Adult	43	-	1,2						1.633	

1 = Temperature 2 = Relative humidity 3 = Sterile eggs 4= Parasites K= 0.367
5 = Predators 6 = Inability to enclose 7 = Unknown factors

4.2.1 Apparent mortality

The data revealed that the apparent mortality during the egg stage was the highest (25 per cent) in the third generation, while it was 17, 22 and 19 per cent in the first, second and fourth generation respectively. Further, when comparison was made within the developmental stages during each generation the apparent mortality was the lowest (12 per cent) in the early instar larval stage of third generation (10.14 per cent) in the late star larvae of fourth generation. As for as the pupal stage was concerned, the apparent mortality was lowest (22 per cent) in the third generation and highest (31.48 per cent) in the second generation. A cursory glance over the respective apparent mortality percentage with respect to all the developmental stages in the third generation revealed that it was highest during the egg stage and in other stages it was of a comparatively low order.

4.2.2 Survival fraction

The survival fraction was the lowest (0.750) at the egg stage in the third generation and it was highest (0.83) in the first generation. However, the variation in the survival fraction in other generations was of a low order. As regards the early instar larval stage, the survival fraction found to be other way round i.e it was highest (0.88) in the third generation, followed by fourth, second and first generation (0.85, 0.82 and 0.77) respectively. When variation in the survival fraction within the developmental stages was concerned, it was interesting to note that there was little variation in the survival fraction in the first generation, whereas there was pronounce variation in the fourth generation. The generation survival fraction in all the generations was as under:

First generation	$S_G = 0.83\ (0.77+0.81)\ 0.79 = 1.036$
Second generation	$S_G = 0.78\ (0.82+0.84)\ 0.68 = 0.880$
Third generation	$S_G = 0.75\ (0.88+0.78)\ 0.78 = 0.971$
Fourth generation	$S_G = 0.81\ (0.85+0.90)\ 0.69 = 0.978$

4.2.3 Real mortality

The data on real mortality revealed that of all the developmental stages, it was maximum at the egg stage in the third and second generations (25 and 22) respectively, whereas, maximum 19 was observed in the early instar larva in the first generation, in contrast to this, the lowest real mortality was (9) in the third generation. As for as the variation within the developmental stages with regard to real mortality was concerned, the lowest was encounterd in the late larval instar stage (7) in the fourth generation, whereas the highest at the egg stage of third generation.

4.2.4 Mortality survival Ratio

The highest ratio (0.333) at the egg stage was observed in the third generation, followed by 0.282, 0.234 and 0.204 in the second, fourth and first generation. Further, the early larval instar stage trend shows a gradual decrease in the mortality survival ratio from first to third generation. The same trend followed in the late larval instar stage in first, second and fourth, whereas, the third generation recorded the highest mortality survival ratio. As for as the mortality survival ratio of all the stages, the ratio of high magnitude was recorded at the pupal stage of second and fourth generation (0.462 and 0.444). It is interesting to note that the variation of low magnitude within the stages in the first generation and of high magnitude in the rest of the generation was found.

4.2.5 Indispensable mortality

The data shows that indispensable mortality during the egg stage was maximum (12.987) in the third generation, while it was least (8.364) in the first generation. Further, the highest value among all the stages was observed (19.092) at the pupal stage of the fourth generation and the least (5.304) at the early instar larval stage of the third generation. The data, further, revealed that the variation of low magnitude in the indispensable mortality among all the stages was observed in the first generation.

4.2.6 k-values

The k-values computed for different stages revealed that in the fourth generation the values were of low magnitude, while it was quite varying in other generations.

The k-values for egg stage was the highest (0.125). In the third generation and lowest (0.081) in the first generation. In contrast to this the trend shows a gradual decrease of k-values in case of early instar larval stage from first to third generation. The reverse trend follows in case of late larval instar stage from third to fourth generation, however, the third generation shows the highest k-values. As far as the pupal stage was concerned, a high k-value encounterd in the fourth generation (0.159) and lowest (0.104) in the first generation. The sum of k-values for all the developmental stages in each generation are:

First generation: K=0.081+0.113+0.090+0.104 = 0.388

Second generation: K=0.108+0.086+0.074+0.164 = 0.432

Third generation: K=0.125+0.069+0.108+0.107 = 0.409

Fourth generation: K=0.092+0.070+0.046+0.159 = 0.367

4.2.7 Trend index and Generation survival

In order to find out the extent of adverse effect of various mortality factors on the population of a particular generation and also to see whether there was an increase or decrease in the pest population in the forth coming generation. Trend index (1) and Generation survival (SG) was calculated (Table 10). A perusal of the numerical information so obtained, in each stage specific life-table for respective generation revealed that the highest value of trend index (1.08) was in the fourth generation followed by third and second generation, whereas, generation survival was highest (0.530) in the fourth generation followed by third, first and second generation.

Table 10. Pest population forecasting through life-table parameters

Parameter	Generation			
	I	II	III	IV
Trend Index (I)= (N_2 / N_1)	-	0.939	0.961	1.08
Generation survival (SG) = (N_3 / N_2)	0.493	0.474	0.520	0.530
Generation survival fractions (S_G)	1.036	0.880	0.971	0.978

N_1 = the number of early instar larvae in the previous generation
N_2 = actual number of early instar larvae in the current generation
N_3 = number of the females x 2 of the current generation

4.3 SURVEY OF PARASITOIDS

During the period of investigation on gram pod-borer-parasitoids-complex interaction a few parasitoids were found to be associated with. The details are presented in the Table-11

Among the parasitoids belonging to the order Hymenoptera the *Campoletis chloridae* Uchida (Fam., Ichneumonidae) and *Tetrastichus ayyari*. Rohwer (Fam., Eulophidae) and of the order Diptera (indet.) (Fam., Tachinidae) were found parasitizing the gram pod-borer.

Study was also conducted with regard to per cent parasitization of larvae- pupae on chickpea crop and the data so obtained are presented in Table-12 based on the data collected, out of cohort of 50 larvae, under the laboratory conditions, revealed that the parasitoid *C. chloridae* made its presence felt throughout the cropping season except with the interruption of few weeks and *T. ayyari* was seen parasitizing at the later half of the crop stage, whereas, parasitoid of Family Tachinidae shows its presence only in a week.

Of the total number of parasitoids the most voracious one was *C. chloridae*. As for as the trend of parasitization was concerned, this exhibited high incidence of parasitism during the last decade of the February and Ist week of March (20 and 30 per cent) and also last week of March (24 per cent). However, from December to first fortnight of January the incidence was very low and at last fortnight of January to third week of February no

Table-11. Natural enemies (parasitoids) of *H. armigera* on chickpea observed during rabi,1998-99 at Dryland Research Station Dhiansar, Jammu.

Order	Family	Scientific name
Hymenoptera	Eulophidae	*Tetrastichus ayyari* Rohwer*
	Ichmeumonidae	*Campoletis chloridae* Uchida**
Diptera	Tachnidae	Indet***

* Larval parasitoid (Early instar)

** Larval parasitoid (Late instar)

*** Larval-pupal parasitoid

Table-12.Field parasitization of *H. armigera* on chickpea during rabi, 1998-99.

Weeks	Occurrence of parastoids (Nos) in cohort of 50 larvae/ pupae (Per cent parasitization)					
	C. chloridae		*T. ayyari*		*Fam. Tachnidae(Dip)*	
	No. of parasitoids	Per cent parasitization	No. of parasitoids	Per cent parasitization	No. of parasitoids	Per cent parasitization
Nov.29-5Dec.,98	3	6	-	-	-	-
6-12	5	10	-	-	-	-
13-19	1	2	-	-	-	-
20-26	3	6	-	-	-	-
Dec.27- 2 Jan.,99	3	6	-	-	-	-
3-9	1	2	-	-	-	-
10-16	6	12	-	-	-	-
17-23	-	-	-	-	-	-
24-30	-	-	-	-	-	-
Jan.31-6 Feb	-	-	-	-	-	-
7-13	-	-	-	-	-	-
14-20	-	-	1	2	-	-
21-27	10	20	5	10	-	-
Feb.28-6 March	15	30	2	4	1	2
7-13	7	14	4	8	-	-
14-20	8	16	5	10	-	-
21-27	5	10	8	16	-	-
Mar.28-3 April	12	24	6	12	-	-
4-10	7	14	4	8	-	-

parasitization was observed. The trend of parasitization shows that the rate of parasitization increases with the increase in maximum temperature. As far as the parasitization of *T. ayyari* was concerned, it was observed that it occurred from third week of February upto the harvest of crop. The maximum parasitization (16 per cent) was during the 21-27, March and no parasitization was observed till second week of February.

A larval-pupal parasitoid of Family Tachnidae (indet.) exhibited parasitization, (2 per cent), though of negligible importance occurred during first week of March only. An interesting observation with respect to these parasitoids was, that *C. chloridae* happened to be more virulent both in the vegetative and reproductive stages than the rest of the parasitoids. Further the range of parasitism with respect to the entire cropping season was from 2-30 per cent.

4.4 EFFECT OF WEATHER PARAMETERS

Since the gram pod-borer was found to occur as a major pest, studies were made to ascertain the role of abiotic factors on its abundance during the cropping season. The data obtained on weather parameters and seasonal incidence of larval population of this pest with respect to the parameters are presented in Tables 13 and Fig. 3. A perusal of the data revealed that during rabi 1998-99, its activity on chickpea continued through the cropping season. However, on critical observation, it was found that the larval activity in the initial stages since the appearance of the pest, continued to rise upto the

Table-13. Effect of weather parameters on population buildup of *H. armigera* on chickpea under the agro-climatic conditions of Dhiansar, Jammu, during rabi, 1998-99.

Week Date	Larval population per m^2	Temperature*(^{0}C)		Relative humidity* (%)		Total rainfall
		Max.	Min.	Max.	Min.	(mm)
Nov.29-5 Dec.,98	4.478	25.11	7.05	84	40	0.0
6-12	5.75	24.00	16.00	89	48	0.0
13-19	6.752	20.20	6.20	94	59	0.0
20-26	3.98	19.50	6.20	97	69	0.0
Dec.27-2Jan.,99	4.26	16.20	3.50	96	84	0.0
3-9	2.55	17.3	9.2	95	82	26.0
10-16	2.55	14.9	6.4	98	85	0.0
17-23	2.417	16.9	8.5	94	86	8.8
24-30	6.184	17.5	6.6	93	68	16.1
Jan.31-6 Feb.	4.096	19.9	5.7	92	55	0.0
7-13	6.610	21.6	9.9	92	67	2.2
14-20	7.579	24.3	11.0	91	51	8.6
21-27	8.032	23.20	9.50	84	53	0.0
Feb.28-6 Mar.	6.61	25.08	10.20	86	54	11.6
7-13	6.468	25.00	12.20	80	55	22.4
14-20	7.890	26.80	13.80	86	49	0.0
21-27	7.464	28.60	12.70	71	33	0.0
Mar.28-3Apr.	9.95	33.10	15.20	69	39	0.0
4-10	3.12	35.30	15.9	57	38	0.0

* Figures show the averages over weeks.

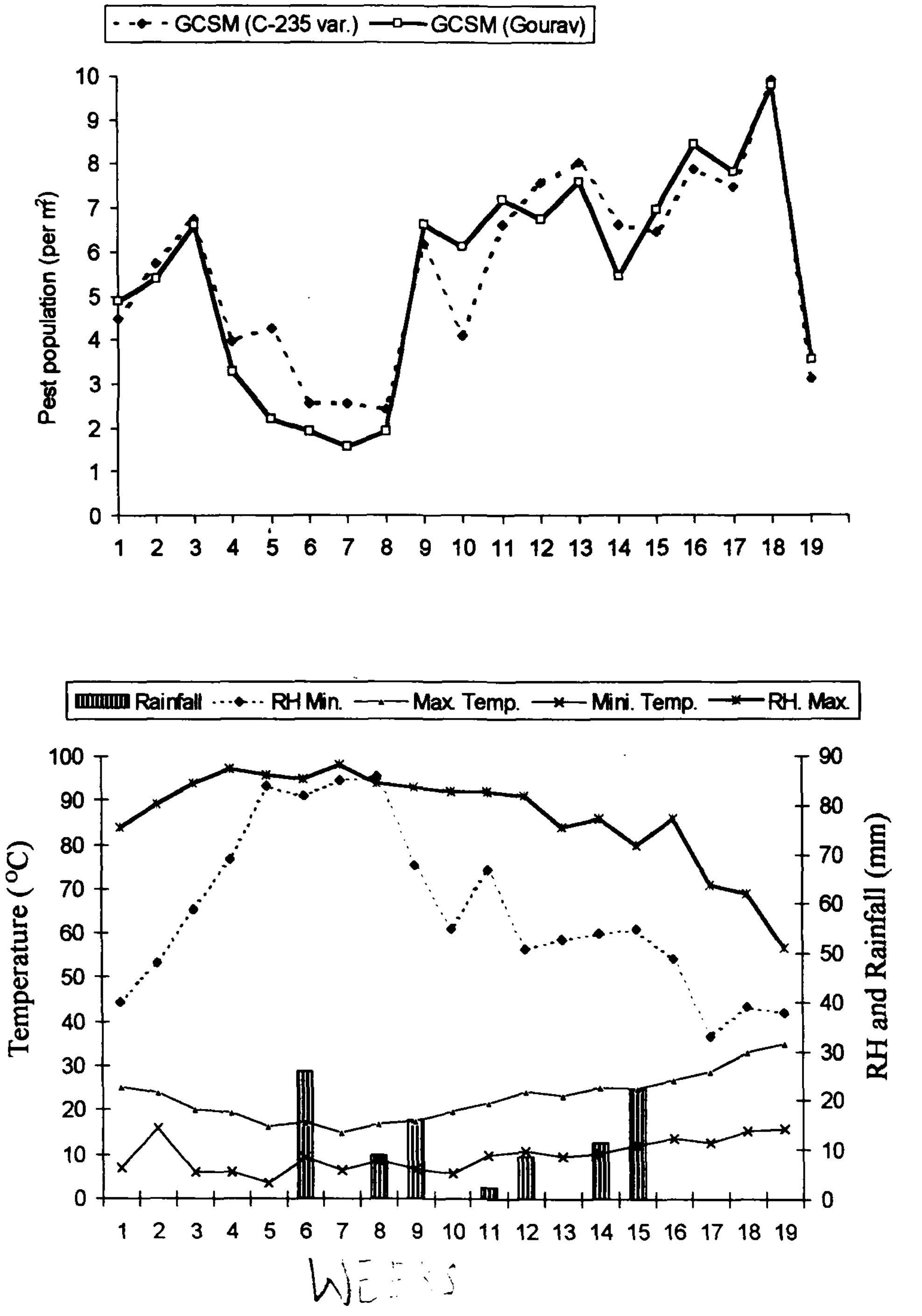

Fig. 3. Weekly population buildup (per m²) of *H. armigera* on chickpea against the weather parameters during rabi, 1998-99 (Observations taken by GCSM)

third week, whereas, its activity had a short decline upto the 8th week, then again there was shoot up in the population density upto the next week and interestingly sharp decline in the next week i.e. the 10th week, after then the graphs shows ups and downs and the maximum peak was during the 18th week and then sharp decline in the next or the last week i.e. the 19th week.

It is interesting to note that almost the same trend follows the pest population density in both the varieties (Timely and late sown).

At a glance, when we see the graph of the pest population with respect to abiotic factors against the weekly build up, the graph shows ups and downs throughout the whole cropping season. In the early stage the maximum population was found in the third week i.e 6.752 larvae per m^2 and the minimum pest population in the 7th week (Gourav var.) and 8th week (C-235 var.). In both the varieties there was a sharp increase in the pest density in the next week then gradual increase and reached its peak upto the 18th week and declined sharp line in the 19th week.

The minimum pest population occurred on 7th or 8th week when the Maximum temperature was 14.9^{0}C and Humidity (Minimum 85%) and no rainfall. The maximum pest density was found on 18th week when the pest population was 9.95 larvae per m^2 and the Maximum temperature 33.10^{0}C and relative Humidity (minimum 39%) and no rainfall. In the next week the pest population sharply declined upto 3.12 larvae per m^2 because the maximum temperature increase upto 35.3°C and relative humidity (Min.) remained almost constant and there was no rainfall.

On comparing the two estimation procedures i.e Ground Cloth-Shake method (GCSM) and Visual Count method (VCM) as regards the population buildup of gram pod-borer, for both the varieties under consideration, GCSM proved to be better one.

In order to study the extent of association and dependence of average population buildup (per m^2) of gram pod-borer with respect to weather parameters, correlation and regression analysis were performed. As regards the association between various parameters, weather as well as pest population). The correlation matrix is presented in the Table-14. At perusal of which indicates that emergence of pest is directly affected by maximum temperature (Max. Temp.) and inversely proportional to Min. RH, these relationships were found to be statistically significant. If we look at other weather parameters, it is observed that its association with the pest population have no statistical significance. However, for these weather parameters the relationships was positive for minimum temperature Whereas in case of Max. RH it was negative. So far as rainfall is concerned it has least effect on population buildup, this might have caused due to the fact that during the present investigation the rainfall was almost nil during most of the weeks as can be seen in Fig. 3.

The simple regression equation along with correlation coefficients (r) gram pod-borer population (y) on Max. Temp. (X1) and Min. RH (X4) were obtained as follows.

Y= 1.18+0.19 X 1 (r=0.51) and Y= 10.09-0.08 X 4(r=0.61) respectively. These equations showed that with a unit increase in the maximum temperature there was increase in pest population by 0.19 per m^2 and with a unit increase in Min. RH there was a decrease of 0.08 pest towards its population.

Further, the combined effect of all the abiotic factors on this pest population buildup was studied through multiple correlation and regression analysis (Table 14 and Fig.4) All the weather parameters when taken collectively showed a contribution of 45.55 per cent towards pest population. However, this joint relationships were found to be statistically non-significant and the model was obtained as: $Y= -4,772+0.209X_1 -0.015X_2 +0.122X_3 -0.087X_4+0.051X_5$ (r=0.6749).

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Table-14. Correlation matrix showing relationship among various factors with regard to gram pod-borer

Variables	Population	Max. Temp.	Min. Temp.	Max. RH	Min. RH	Rainfall (mm)
Population	1.00	-	-	-	-	-
Max Temp.	0.51*	1.00	-	-	-	-
Min Temp.	0.41	0.81*	1.00	-	-	-
Max. RH	- 0.37	- 0.93*	-0.73*	1.00		
Min. RH	- 0.61*	- 0.88*	-0.65*	0.77*	1.00	
Rainfall	- 0.05	- 0.24	-0.01	0.17	0.32	1.00

* Marked correlations are significant at $p < 0.050$
$n = 19$

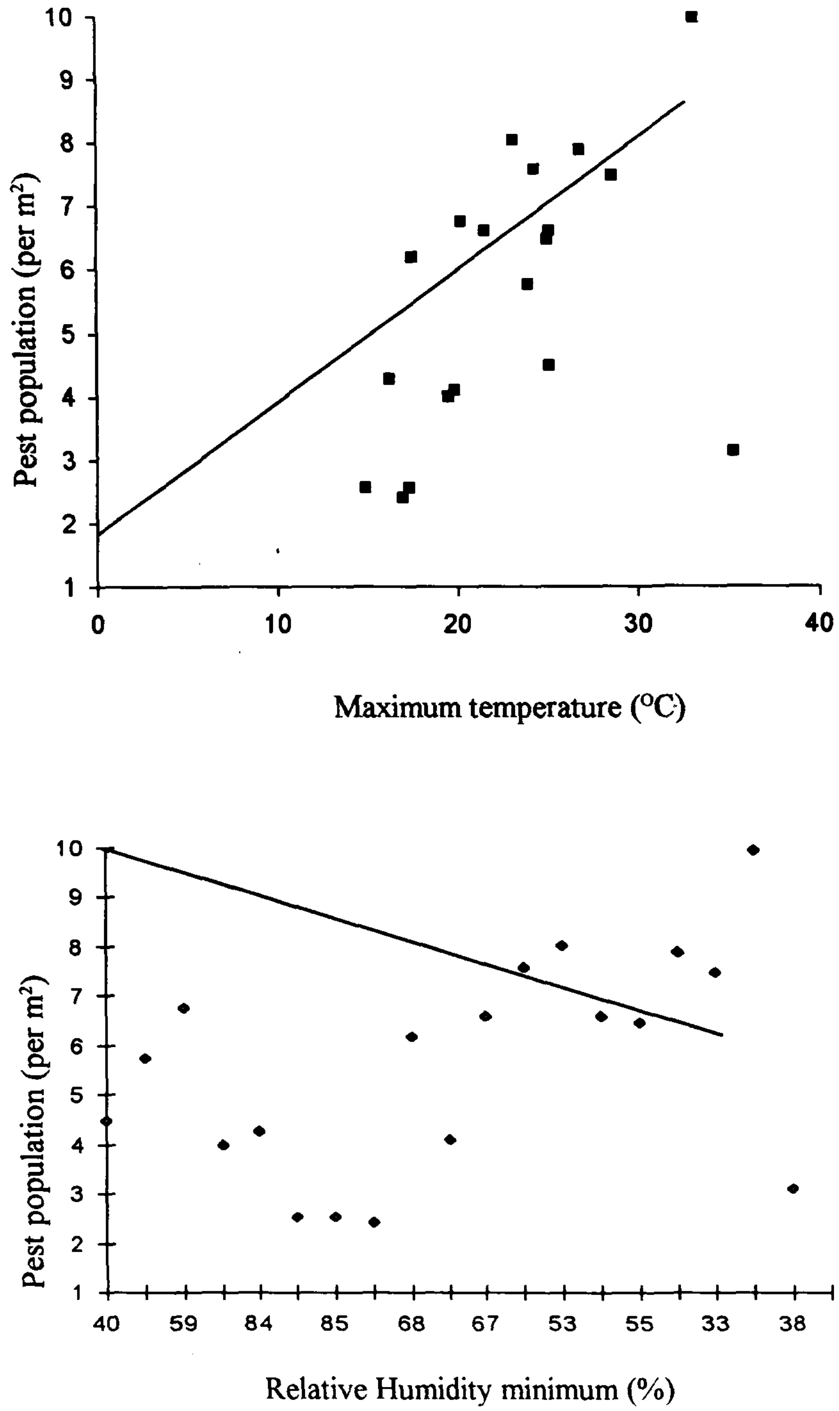

Fig.4. Scatter diagram regression and correlation showing association of pest population with respect to weather parameters.

DISCUSSION

5. DISCUSSION

5.1 ESTIMATION OF POPULATION

For studies on the population dynamics of gram pod-borer in the field experiment, it is essential to estimate the population density at different crop growth stages, for the efficient and precise sampling techniques which is basic for any IPM strategies. Considering the importance of the problem, investigations were conducted to determine the efficient and precise method of sampling and optimum sample unit size required to estimate larval population of gram pod-borer on chickpea. The observations taken for the estimation of population of gram pod-borer being deciphered under the following sub heads:

5.1.1 Mean population values by GCSM and VCM

The weekly observations taken for the count of population density per m^2 by GCSM and VCM on the timely and late sown varieties clearly indicates that the number of counts were more when the observations were taken by GCSM than VCM. In the present findings on an average, 5.653 and 5.480 larvae (by GCSM), whereas, 4.938 and 4.638 larvae (by VCM) on plants of per m^2 were counted on timely sown and late sown variety respectively (Tables 1-2). These findings confirm the findings of Kaushik and Naresh (1989).

5.1.2 Relative net precision value (RNP values by GCSM)

When a comparison among three sample unit sizes viz., 0.5, 1.0 and 1.5 m row length were made in both the varieties, the RNP values were found to be significantly higher in case of sample unit size of 1.0 m row length than the other sample unit sizes. Thus it can be said that the sample unit size of 1.0 m row length gives better estimate as compared to sample unit sizes of 0.5 and 1.5 m length (Table-3). the same results were obtained by Kaushik and Naresh (1989) where, in the last four weeks of observations, even 0.5 m row length gave desired estimates and there was, no significant difference between 1 and 1.5 m unit sizes. Abraham *et al.* (1963) reported that sample unit size of 2'x2' was most efficient for estimation of stem borer infestation in rice. Population of cotton arthropods was estimated by Pieters (1978), using 30, 7.5, 4 and 1 m row length and concluded that smaller sample size tended to have greater standard error at a fixed cost per sample unit size.

5.1.3 Sample unit sizes (Table-4)

When the unit sizes for the estimation of population in both the varieties, by GCSM and VCM the count on 0.5 m row length was found to be more biased and overestimated and the population count on 1.5 m row length was underestimated, whereas the population count on 1.0 m row length seems to be more precise and less biased with regards to RNP values. These finding conforms the findings of Kaushik and Naresh (1989) where they that the sample unit size of 1.0 m row length was more precise than 0.5 m and more economical than 1.5 m.

5.1.4 Comparison of GCSM with VCM

Data presented in the Table-5 and Figs. 1 & 2 revealed that during the whole cropping season, under observation, average number of gram pod-borer larvae obtained in both the varieties by GCSM were significantly greater ($P<0.05$) than by VCM. A simple reason for the difference in both the observations i.e. GCSM and VCM may be that the small size of the pest in early stage and the colour of the larvae resemble the crop plant, the young larvae as well as pod can very easily ,be missed under the plant canopy, or feeding in flower and pods by VCM. The Ground Cloth-Shake Method was highly efficient in collecting the gram pod-borer larvae which tend to fall from the plant when disturbed then the method used in Visual Counting. However, by GCSM, there is every possibility of dislodging all the larvae present on the plants and taking less time for proper counting and records.

Relative variation (SE/x x100) is used to describe the variation of a sampling method over a variety of sampling units (Pedigo *et al.* 1972). Since variation is a function of the number of subsamples taken and, thus, a function of the time required to complete the entire sample, any criteria for comparing time required to complete the sample must take into account the variation. Such a criterion is the relative net precision, (RNP = 1/ RV(%)xTime) (where time means the period consumed in man hour) (Pedigo *et al.*, 1972, Southwood, 1966).

When a comparison between the GCSM and VCM, taken into account in both the varieties, it was found that RV was less and RNP was more and also the time taken for counting the pest population during observation was less in case of GCSM as compared to Visual Count Method.

According to Kaushik and Naresh (1989) that when the time factor involves, 1.0 m row length unit size can safely be utilized to estimate larval population of gram pod-borer by using GCSM. Studies on different methods of sampling of soybean orthopods including *Heliothis*, revealed that GCSM was the best (Boyer and Dumas, 1963; Carner *et al.*, 1974; Hillhouse and Pitere, 1974; Turnipseed, 1974; Kaushik and Naresh, 1989).

From these findings it may safely be concluded that the sample of 1.0 m row length unit size per plot using GCSM was more practical, efficient, economical and reasonably accurate for estimation of larval population of gram pod-borer on chickpea.

5.2 LIFE-TABLE STUDIES (STAGE SPECIFIC)

The life-table of gram pod-borer with respect to various developmental stages for four consecutive generations revealed very distinct and varying trends as far as the survival of the species was concerned. The trend index (I) value during the second generation was found to be less than unity. In other words the negative value of the trend index (0.939) indicated that the mortality factors operating during this period were most effective in causing a decline in the pest population. This factor was further reflected in the generation survival value (SG) and also the generation survival fraction (S_G), thereby, the crop being allowed to grow unhindered. Further, there was low survival in the second generation which was the lowest in comparison to the first, third and fourth generations, giving much credence to the negative trend index values. A comparison of the key mortality factors showed that the generation survival during the second generation was affected almost at the all stages of development by the factors responsible to suppress the population. In contrast to this, generation survival was least affected during the third and fourth generation further, the reduction in the number of reproducing female in the second generation seemed to be the direct consequence of high k-value (0.164) in the pupal stage.

The trend index (I) value during the fourth generation was found to be more than unity. In other words, the positive value of the trend index (1.08) indicated that mortality factors operating during this period were not effective in causing a decline in the pest population. This factor was further reflected in the generation survival value and also the generation survival fraction. If viewed, from another angle, the positive trend index obtained in a generation indicated increase in the pest population in the coming generation a view held by Roy and Bains (1983) and also supported by Gurs (1995).

The trend shown by the trend index is that it was less than unity in the second and third generations and more than unity in the last or fourth generation. Same trend in the generation survival is being replicated where second generation shows the minimum generation survival and maximum in third and fourth generations.

Similar attempt in the past were made to construct ecological life-table in order to use them as the tools to study the population of insects as early as in 1969, Harcourt opined that such table recorded in series of sequential measurements that indicated population changes throughout the life-cycle of a species in its natural environment. And when these measurements were related to mortality, the life-tables formed a budget of successive processes that operated in a given population. Atwal and Singh (1974) constructed a similar life-table for determining key mortality factors of *Chilo partellus* that the trend index values of less than unity pointed towards different mortality agents contributing to the generation mortality of *C. partellus* during the pre-monsoons and post-monsoons period. The observations of Gurs (1995) also strengthen the said findings. Their observations corroborate fully the present observations on gram pod-borer as far as the four generations were concerned. The research findings of Bilapate *et al.* (1979) on *Heliothis armigera* Hub., Roy and Bains (1983) on *Tryporyza nivella* F. and Sharma and Bhalla (1992) on *Metasyrphus corollae* (F.), a predator of the cabbage aphid also strengthen the present findings. However, the positive value of the trend index obtained in the fourth generation during the course of present study find full support in the work of Bilapate *et al.* (1979). Lastly, the sum of the k-values obtained of all the developmental stages in each generation indicated that it was in the second and third generations where different mortality factors were greatly responsible for decline in the pest population. The trend indicated that the mortality factors failed to cause appreciable decline in the fourth generation of pest population needed to apply control measures for the control of larval population buildup of gram pod-borer.

While the study of life-table of forecast may safely be made as to when and at what stage of crop development, a control measures would be of paramount importance of safeguard it against the menacing effects of insect-pests.

5.3 SURVEY OF PARASITOIDS

Among the various insect-pests attacking the chickpea crop, pod-borer was the most important one which inflicted heavy damage at the larval stage from the vegetative stage through to the harvesting period. Attempts in the past were made to study the natural enemies of this pest and inoculative studies were also made by utilizing a number of parasitoids. The data which deals with the parasitoid-complex associated with this pest in quantitative estimation made on parasitism, is being discussed here as under:

Of the three parasitoids encountered in the present study, *Campoletis chloridae* Uchida (Hym; Ichneumonidae) was observed as the most voracious natural enemy of gram pod-borer. According to Singh (1988), it is most widely distributed parasitoid from the Himalya to the sea-level and the parasitism exceeds 35 or even 83 per cent.

In the present study, the initial parasitism by this parasitoid was encountered in the first week of December and the parasitization was very low. This observation conform the findings of Mattoo (1998), in contrast to the studies made by Yadav and Patel (1981), who reported that the parasitization was maximum during December and minimum during February and no parasitization was observed during last fortnight of January upto third week of February. In the studies made herewith no parasitization was observed from third week of January upto third week of February. The lowest parasitization during February was also recorded by Singh *et al.* (1983), whereas in the present study 20 per cent parasitization was observed during 21-27 February.

The highest per cent parasitization was observed during the first week of march (30 per cent). In the beginning of April, the parasitization was 24 per cent and then dropped in the second week and no parasitization during the later days of the month was observed. These finding corroborates the findings of Mattoo (1998). However, Garg (1989), reported, that the rate of parasitization recorded from third week of April, then gradually increase and reach to the maximum in the last week of May. According to Pawar *et al.* (1989), in Andhra Pradesh, the percentage parasitism was highest in December and lowest in May. However, in the present studies, due to different agro-climatic conditions and the non availability of chickpea no studies were made. Present observation corroborate the findings of Mishra *et al.* (1992), who observed the activity of parasitoid during the months of December and January, though in the present study the parasitoid was active only in the month of December upto the first fortnight of January. This conforms the findings of Mattoo (1998). During the second fortnight of December, the degree of larval parasitization (6.1 per cent) was reported by Natrajan and Sundramurthy (1988) and Mattoo (1998), though in the present study very low parasitism was observed, whereas, Prasad *et al.* (1989) recorded 50-53 per cent parasitization during the month of December, though Shrivastva and Yadav (1991) indicated 61.9 and 16.66 per cent in Madhya Pradesh.

It was quantitatively evaluated that throughout the cropping season the parasitization was 2-30 per cent, but it was important to note that the parasitoid did not appear at all between the second fortnight of January and third week of February and also at the harvesting period.

A striking observation about the population dynamics of this pest was that the free moisture available in the early stages of the crop and the gradual decrease in temperature and also a gradual increase in temperature was highly conducive for the activity of this parasitoid.

Another parasitoid, *Tetrastichus ayyari* Rohwer (Hym; Eulophidae) shows its appearance during the last fortnight of February till the second week of April. It was quantitatively evaluated that, though this parasitoid shows its presence at the later half of the crop stage and the rate of parasitization ranged from 2-16 per cent. But it was important to note that this parasitoid did not appear during the first half of the cropping stage and also at the time of harvesting. The same findings were recorded by Mattoo (1998). The highest parasitization was between later half of March to first week of April (10-15) per cent). The parasitoid, though, appeared in the field for a short period, however, of lesser importance, but of high potential due to medium range of parasitization.

The other parasitoid of Family Tachinidae (indet.) was of no consequence, as it did not exercise any significant control over the pod-borer as it appeared in the field for a very short period i.e. first week of March and the parasitization was only 2 per cent.

A striking resemblance in the observation, in the population dynamics of these natural enemies of gram pod-borer was that as the three parasitoids were present during later half of the crop and first two parasitoids showed high degree of parasitization, only *C. chloridae* was active at the vegetative phase of the crop. The statement of Ravi and Verma (1997) is true in the present finding with regard to

C. chloridae that the parasitization remain low in the early stage, gradually increased, then decline due to rise in temperature.

Finally, it could, therefore, be inferred from the foregoing discussion with that if manipulated according to specification, the first two parasitoids might prove to be a potential source for suppressing the population of gram pod-borer.

5.4 EFFECT OF ABIOTIC FACTORS ON PEST DENSITY

There are several reports in the literature pertaining to the pest (gram pod-borer) activity on chickpea crop during its entire growing season. As early as 1979, Patel reported that the temperature (10.5°C), high relative humidity (60-70 per cent) and rainfall (3-5 mm) are the critical factors on the incidence of the pest. Dakwale and Singh (1984) reported that the infestation had begun in January and reached its peak in last week of February, when the temperature was 37°C and RH 46 per cent at Rewa, Rajasthan. Yadav and Lal (1988) inferred that the population was positively correlated with maximum and minimum temperature and negatively with RH and percentage parasitism. In direct agreement to these studies the population of pest increases with the gradual increase in the maximum temperature and negatively correlated with the minimum RH and rainfall and per cent parasitization (parasitization at the pod formation stage). The present findings are not in agreement to those of Prasad *et al.* (1989) who reported the peak of infestation on 11 February and Ist week of March. In another report Patel and

Koshiya (1997) demonstrated that the pest population reached its peak during 2nd and 3rd week of January (1992-93) and December (1993-94), then the population declined gradually and disappeared upto the end of January, 1993 and February, 1994, respectively. Their observations clearly indicate that the pest was active from November to February.

The present data showing high rainfall resulting in decrease in pest population conform the findings of Yadav and Lal (1988). The findings made by Mattoo and Singh (1998) are of direct agreement to the present findings.

An interesting study made by Prasad *et al.* (1989) was that fairly low population of the pest encountered at the different period was due to high rate of parasitization. The study made by Mattoo (1998) was that low infestation by the pest at the period of pod-formation stage was due to parasitization by *C. chloridae, B. lasus and T. ayyari* holds true in the present finding, where *C. chloridae and T. ayyari* (parasitoids) felt their presence.

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SUMMARY AND CONCLUSION

6. SUMMARY AND CONCLUSION

The present investigation on the management of major insect-pest, *Helicoverpa armigera* (Hub.) on chickpea, an inventory was made on the population dynamics under varying weather factors in the prevailing agro-climatic conditions at Dhiansar, Jammu which is essential to estimate the population density at different crop growth stages for the efficient and precise sampling technique which is basic for any integral pest-management (IPM) programme. Considering the importance of the problem, investigations were conducted to determine the efficient and precise sampling technique to estimate larval population of gram pod-borer on chickpea. It is worth mentioning here that prior to embarking upon investigation on the study on the population dynamics of natural enemies with respect to growing season of chickpea, an humble attempt was made to study the life-table of *H. armigera*. In the hind-sight, the idea was to see, if the informations (by field parasitization) so generated would be of some help of designing a biological tool to minimize the incidence of larval pest on chickpea crop. Further, in order to have an idea of larval incidence and the extent of damage it could inflict on the chickpea crop with a view to understand the behavioural pattern of insect-pest attacking the chickpea crop under varying weather factors (Abiotic factors) in the prevailing agro-climatic conditions at Dhiansar in Jammu. In the following paragraphs an overview of the results obtained in the present investigation is mentioned.

In order to study the population dynamics of gram pod-borer, investigations were carried out on two varieties of chickpea (C-235, timely sown and Gourav, late sown var.) at Dhiansar, Jammu revealed that ground cloth shake method (GCSM) was more efficient, accurate and practical than visual count method (VCM). Sample unit size of 1.0 m row length was more precise than 0.5 m and more economical than 1.5 m row length.

In order to find out the key factor responsible for the fluctuation in the population in different generation occurring in the same season of the crop, stage specific life-tables were constructed.

The life-table (stage specific) of gram pod-borer with respect to various development stages for the four consecutive generations revealed that the trend index value (I) in the fourth generation was more than unity, whereas, in rest of the generation the trend index was less than unity. Further, the generation survival (SG) in the fourth generation was found to be 0.520 which corresponded well to the I-value. As for as the SG value in rest of the generation is concerned also corresponds the I-Value of the same generation. These observations were, further, strengthened by generation survival fraction (SG) which was 1.036, 0.880, 0.971 and 0.978 for the first, second, third and fourth generations respectively, The k-value gave an indication of the generation survival and its extent. The values obtained in the last or fourth generation were far much lower in comparison to that observed in previous generations in all the stages. Further, the less number of reproducing females (18) in the second generation was the result of high k-value (0.164) in the pupal stage as compared to other generations.

Lastly, the sum of k-values obtained for all the developmental stages, it was the highest in the second generation (0.432) followed by third (0.409), first (0.388) and fourth (0.367) generations. With the help of these values, it can be inferred that it was only in the second generation, where all the mortality factors were greatly responsible in reducing the population buildup.

It is said that natural enemies, if present, always have a bearing on the population dynamics of a pest. Besides this, it is also a widely known fact that the extent of natural enemies is inversely proportional to the incidence of pest (on which the enemy parasitizes). In the present findings, the total number of parasitoids encountered belonging to the order Hymenoptera viz., *Campoletis chloridae* Uchida (Fam., Ichneumonidae), *Tetrastichus ayyari* Rohwer (Fam., Eulophidae) and a Tachinid (Indet.) (Order, Diptera, Family. Tachinidae) were found parasitizing the pest during the cropping season. Of the total number of parasitoids, *C. chloridae* was the one which had a very high voracity and exhibited high intensity of parasitism during 14th week (28th Feb.-6th March, 99) (30 per cent), though the parasitoid remained in the field for maximum period of the crop, from vegetative phase to the pod formation phase, where the incidence of parasitism was irregular, high and low and disappeared during almost at the midle of the season and at the harvesting period. Another parasitoid, *T. ayyari* happened to be comparativley less virulent (parasitization 2-12 per cent) because it appeared during the later half of the cropping stage and was compeletely absent during the vegetative phase. Only one parasitoid, tachinid (indet.) was collected during the cropping season.

The vagaries of weather parameters on the incidence of pod-borer clearly revealed that the abiotic factors have pronounced bearing on the pest poulation during the cropping season. When weekly population buildup with regard to the overall weather scenario of the season was taken into consideration, the data revealed that max. temp. was positively correlated and RH (min) was negatiely correlated with the pest population.

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LITERATURE CITED

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* Original not seen

APPENDICES

Appendix I

Week	Temperature (°C) Max	Min	Relative Humidity(%) Morning RH1	Noon RH2	Total rainfall (mm)
Oct.15-98	27.0	20.4	86	65	-
16	22.0	18.6	87	87	25.6
17	22.0	17.4	98	98	22.0
18	29.6	16.4	91	78	9.8
19	30.8	19.6	86	67	-
20	31.6	18.4	76	57	-
21	31.8	16.4	82	58	-
22	32.4	16.6	85	48	-
23	31.6	16.9	96	51	-
24	31.0	17.5	80	57	-
25	32.2	17.4	79	50	
26	31.8	16.4	70	46	-
27	31.0	13.3	65	41	-
28	32.0	13.0	55	39	-
29	31.2	15.4	66	47	-
30	30.0	12.6	48	35	-
31	31.0	13.0	55	36	-
Nov.1-98	31.4	13.4	68	41	-
2	30.4	14.0	68	33	-
3	31.0	13.4	57	39	-
4	29.0	13.4	75	48	-
5	28.0	13.8	87	44	-
6	27.4	14.0	78	48	-
7	29.0	15.2	62	43	-
8	28.0	14.4	88	39	-
9	28.0	12.4	62	43	-

Conti........

Week	Temperature (°C) Max	Min	Relative Humidity(%) Morning RH1	Noon RH2	Total rainfall (mm)
10	28.2	12.0	92	40	-
11	28.2	12.4	84	47	-
12	27.6	12.2	79	46	-
13	27.0	12.4	85	44	-
14	27.4	11.4	89	51	-
15	27.8	12.8	80	50	-
16	26.6	10.0	85	40	-
17	28.5	10.4	66	41	-
18	27.6	10.8	68	41	-
19	27.6	12.5	78	50	-
20	27.0	11.2	85	48	-
21	27.6	10.2	80	45	-
22	27.4	12.8	86	42	-
23	28.4	13.2	86	52	-
24	27.0	10.8	78	40	-
25	26.4	11.0	93	46	-
26	26.0	10.2	84	49	-
27	25.4	8.6	82	42	-
28	25.5	7.5	77	39	-
29	26.2	7.2	81	39	-
30	26.0	6.7	81	33	-
Dec. 1-98	25.0	6.4	76	37	-
2	24.4	7.0	79	41	-
3	24.0	7.4	92	40	-
4	25.0	7.2	92	44	-
5	25.2	7.5	87	46	-
6	25.0	8.0	89	45	-

Conti.......

Date	Temperature (°C)		Humidity (%)		Rainfall (mm)
	Maximum	Minimum	RH1	RH2	
7	25.5	7.9	87	47	-
8	25.0	8.0	90	42	-
9	22.5	7.9	78	47	-
10	22.6	8.4	97	50	-
11	23.4	8.0	95	52	-
12	23.6	8.5	89	58	-
13	20.0	8.0	92	46	-
14	22.8	8.5	89	58	-
15	21.4	7.4	94	44	-
16	20.5	6.6	97	54	-
17	17.5	4.8	100	71	-
18	17.0	4.0	100	73	-
19	19.3	5.0	85	64	-
20	24.0	9.5	94	48	-
21	23.5	7.6	86	45	-
22	22.0	7.0	97	58	-
23	20.5	5.6	100	83	-
24	19.0	5.5	100	86	-
25	17.8	4.6	100	73	-
26	10.0	3.8	100	89	-
27	9.4	3.5	100	84	-
28	12.5	1.3	94	83	-
29	16.5	3.2	97	85	-
30	19.5	4.0	97	79	-
31	19.5	5.0	92	84	
Jan. 1-99	19.0	4.0	94	79	-
2	17.2	10.3	97	87	-
3	19.5	12.4	100	75	-

Conti....

Date	Temperature (°C)		Humidity (%)		Rainfall (mm)
	Maximum	Minimum	RH1	RH2	
4	19.7	14.8	95	88	-
5	21.2	15.8	88	64	-
6	14.4	12.8	100	95	-
7	12.6	11.5	100	95	20.00
8	17.6	13.0	97	80	6.00
9	16.2	12.2	87	78	-
10	14.0	9.9	97	83	-
11	16.0	12.2	97	86	-
12	14.9	12.2	95	84	-
13	16.0	10.4	100	78	-
14	14.9	9.5	100	88	-
15	13.7	9.3	97	88	-
16	15.0	10.4	97	90	-
17	16.4	11.4	94	93	-
18	15.6	10.8	100	80	-
19	14.0	10.8	92	88	-
20	15.4	12.5	88	96	2.6
21	15.5	12.9	95	95	3.6
22	23.4	15.9	95	79	2.6
23	18.6	11.5	95	71	11.0
24	16.0	13.0	94	73	-
25	20.6	13.9	94	47	-
26	18.5	11.7	94	67	-
27	17.0	11.0	94	76	4.3
28	13.0	9.2	92	85	0.8
29	19.0	12.3	91	59	-
30	19.0	13.5	94	70	-
31	20.0	13.7	94	47	

Conti.....

Date	Temperature (°C) Maximum	Minimum	Humidity (%) RH1	RH2	Rainfall (mm)
Feb. 1-99	20.6	12.8	89	43	-
2	20.4	13.2	91	41	-
3	19.5	12.0	94	50	-
4	21.8	13.3	91	62	-
5	20.6	13.3	94	57	-
6	16.4	11.4	91	86	-
7	14.6	10.4	91	75	-
8	19.0	15.2	97	80	1.0
9	25.0	16.6	94	54	1.2
10	23.0	17.4	91	70	-
11	25.0	18.0	81	57	-
12	20.4	16.0	95	80	-
13	24.0	16.5	95	56	-
14	25.0	17.7	95	61	-
15	24.2	17.4	90	60	-
16	23.5	18.4	89	48	-
17	25.2	18.9	95	51	-
18	24.4	17.2	92	48	-
19	24.2	17.3	100	42	-
20	24.0	16.9	76	47	8.6
21	23.8	15.7	81	57	-
22	20.6	16.5	95	76	-
23	20.4	16.8	93	50	-
24	23.4	17.5	80	55	-
25	24.8	16.5	78	40	-
26	23.9	15.1	81	46	-
27	25.4	16.5	80	48	-
28	25.0	17.1	95	49	-

Conti......

Date	Temperature (^{o}C)		Humidity (%)		Rainfall (mm)
	Maximum	Minimum	RH1	RH2	
Mar. 1-99	24.0	9.4	72	52	-
2	26.4	8.4	88	53	-
3	26.0	10.8	93	40	-
4	21.8	12.0	82	74	-
5	25.6	12.8	80	61	1.6
6	26.8	13.0	93	49	-
7	23.2	17.6	52	84	-
8	24.2	14.5	100	75	22.4
9	25.2	10.6	80	54	-
10	25.5	13.0	89	43	-
11	25.0	10.2	82	39	-
12	25.5	10.5	76	45	-
13	25.5	9.6	81	42	-
14	26.0	8.5	86	61	-
15	26.2	11.2	86	51	-
16	26.5	11.4	86	52	-
17	27.0	14.4	87	50	-
18	28.5	12.6	89	33	-
19	25.4	13.5	76	46	-
20	28.0	11.8	93	47	-
21	24.0	10.5	83	35	-
22	27.6	10.8	88	42	-
23	29.2	12.5	67	43	-
24	29.0	16.4	76	27	-
25	29.6	14.4	58	22	-
26	30.0	14.6	58	34	-
27	30.5	10.0	68	27	-

Conti......

Date	Temperature (°C)		Humidity (%)		Rainfall (mm)
	Maximum	Minimum	RH1	RH2	
28	32.4	12.2	66	36	-
29	31.5	14.8	75	42	-
30	35.0	15.0	70	25	-
31	32.8	18.0	65	45	
Apr.1-99	34.0	18.0	68	56	-
2	34.4	14.9	65	34	-
3	31.4	13.8	72	37	-
4	34.0	13.5	70	56	-
5	34.8	14.4	67	38	-
6	34.6	16.0	62	38	-
7	35.5	16.8	60	38	-
8	35.5	15.2	56	31	-
9	35.8	17.0	43	41	-
10	37.8	18.4	40	25	-

Appendix-II

(a)

Anova table for variety C-235 (GCSM)

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Calculted F value
Weeks	18	64.095	3.5608	7.27**
Unit sizes	2	24.441	12.2205	24.94**
Weeks vs unit sizes	36	0.9797	0.0272	0.056ns
Error	228	111	0.490	
Total	284			

** Significant at 1% level of significance
ns-Non-significant

(b)

Anova table for variety C-235 (VCM)

Source of variation	Degree of freedom	Sum of squares	Mean sum of squares	Calculted F value
Weeks	18	72.6879	4.0382	8.75**
Unit sizes	2	15.1266	7.5633	16.39**
Interaction	36	9.4775	0.2632	0.58ns
Error	228	105.2490	0.4616	
Total	284			

** Significant at 1% level of significance
ns-Non-significant

(c)

Anova table for variety Gourav (GCSM)

Source of variation	degree of freedom	Sum of squares	Mean sum of squares	Calculted F value
Weeks	18	90.1487	5.0082	11.01**
Unit sizes	2	26.3207	13.1603	28.92**
Weeks vs unit sizes	36	17.9642	0.4990	1.09ns
Error	228	103.7439	0.4550	
Total	284			

** Significant at 1% level of significance
ns-Non-significant

(d)

Anova table for variety Gourav (VCM)

Source of variation	degree of freedom	Sum of squares	Mean sum of squares	Calculted F value
Weeks	18	96.815	5.378	17.74**
Unit sizes	2	12.369	6.184	20.41**
Interaction	36	16.694	0.463	1.53*
Error	228	69.122	0.303	
Total	284			

** Significant at 1% level of significance
* Significant at 5%