“Investigations on Damaging Potential of *Chilo partellus* Swinhoe and Standardization of Multiplication Technique of *Cotesia flavipes* Cameron in Southern Rajasthan”

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Thesis

Submitted to the

Maharana Pratap University of Agriculture and Technology, Udaipur

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for the degree of

Doctor of Philosophy in Agriculture

(Entomology)

By

Suman Manjoo

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Maharana Pratap University of Agriculture and Technology, Udaipur

Rajasthan College of Agriculture, Udaipur

CERTIFICATE-I

Dated : / /2011

This is to certify that **Mrs. Suman Manjoo** has successfully completed the Preliminary Examination held on 06.06.2009 as required under the regulation for the degree of **Doctor of Philosophy** in Agriculture.

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CERTIFICATE-II

Dated : / /2011

This is to certify that the thesis entitled **"Investigations on Damaging Potential of *Chilo partellus* Swinhoe and Standardization of Multiplication Technique of *Cotesia flavipes* Cameron in Southern Rajasthan"** submitted for the degree of **Doctor of Philosophy in Agriculture** in the subject of **Entomology**, embodies bonafide research work carried out by **Mrs. Suman Manjoo** under my guidance and supervision and that no part of this thesis has been submitted for any other degree. The assistance and help received during the course of investigation have been fully acknowledged. The draft of this thesis was also approved by the advisory committee on 27.11.2010.

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Dated : / /2011

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"Investigations on Damaging Potential of *Chilo partellus* Swinhoe and Standardization of Multiplication Technique of *Cotesia flavipes* Cameron in Southern Rajasthan"

Mrs. Suman Manjoo* — Ph.D. Scholar

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ABSTRACT

The "Investigations on Damaging Potential of *Chilo partellus* Swinhoe and Standardization of Multiplication Technique of *Cotesia flavipes* Cameron in Southern Rajasthan" were carried out at Instructional Farm and Maize Entomology Laboratory, Department of Entomology of Rajasthan College of Agriculture, Udaipur, Rajasthan during *kharif* 2008 and 2009. The data recorded on Leaf Injury Rating (LIR) on HQPM-1 and African tall after release of varied number of neonate stem borer larvae, 4 to 32 / plant, clearly express the difference in the resistance potential of cultivar. The cultivar HQPM-1 could shown the resistance against 20 larvae / plant by giving LIR 5.81 and 5.90 during 2008 and 2009 respectively while African tall could tolerate only 8 larvae / plant by recording 5.36 and 5.19 LIR during 2008 and 2009 respectively. Further release of 24 to 32 larvae / plant in HQPM-1 resulted in varied LIR, 6.87 to 8.92 in 2008 and 6.76 to 8.89 in 2009, wherein African tall gave 8.93 to 9.00 LIR during test years. Increase in number of larvae released also had significant effect on plant height wherein drastic reduction was observed after release of 20 larvae / plant in African tall compared to HQPM-1. Maximum tunnel numbers 1.40 and 1.33 per plant in HQPM-1 were recorded with release rate of 24 larvae / plant while in African tall it was 2.37 and 2.36 during 2008 and 2009 respectively at the release rate of 16 larvae / plant. The longest tunnel length (9.29 and 8.43 cm) was observed with release of 24 larvae/ plant during 2008 and 2009 respectively in HQPM-1 while in African tall tunnel length increased from 4.61 to 15.32 cm per plant with gradual increase in number of larvae that is 4 to 16 per plant in 2008. Similarly in 2009 it ranged from 6.14 to 15.19. The data showed gradual increase of tunnel length up to release of 24 larvae / plant and thereafter dead hearts were received. Minimum plant yield in HQPM-1 was 7.58 and 7.10 g / plant was obtained after

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release of 32 larvae / plant during 2008 and 2009, respectively whereas in African tall 0.00 g / plant minimum yield was observed after release of 24 larvae/plant during 2008 and 2009. The results showed gradual decrease in yield with increase in number of larvae released / plant. All treatments were significantly different to each other.

The correlation between yield and the combined effect of independent variables viz. LIR, plant height, tunnel number and tunnel length on yield during 2008 and 2009 was highly significant with R=0.993 and 0.995 in HQPM-1 and R=0.983 and 0.999 in African tall during 2008 and 2009 respectively. Correlation between LIR and plant height of HQPM-1 and African tall showed significant negative correlation. Correlation between LIR and tunnel number as well as LIR and tunnel length was negative but non significant. The observations recorded on correlation between LIR and yield in test corn showed highly significant negative correlation in HQPM-1 (r = -0.983 and -0.982) and in African tall (r =-0.945 and -0.989) during 2008 and 2009 respectively which expressed that increase in the LIR decreased the yield. Plant height and tunnel number as well as plant height and tunnel length in HQPM-1 and African tall showed positive correlation but non significant in HQPM-1 while significant in African tall. The data obtained on plant height and yield of HQPM-1 (r = 0.978 and 0.985) and African tall (r = 0.839 and 0.907) showed highly significant positive correlation during 2008 and 2009, respectively. Tunnel number and tunnel length showed highly significant positive correlation in HQPM-1 r = 0.955 and 0.959 and in African tall r = 0.996 and 0.985 during 2008 and 2009 respectively. The correlation between tunnel number and yield as well as tunnel length and yield was found non significant.

The preference of 17 and 20 days old larvae of *C. partellus* for parasitization by *C. flavipes* were highest where maximum parasitization, 82.61 and 82.46 per cent and 43.09 and 42.70 cocoons respectively were obtained. A significant positive relationship between ages of host larvae and parasitization as well as host age and number of cocoons was obtained while sex ratio did not affected by larval age. Parasitization and number of cocoons in different sized ovipositional chamber showed that maximum parasitization, 89.56 per cent and maximum cocoons 37.53 were recorded in test tube. The sex ratio recorded in test tube was statistically superior to pearl pet jar of 1000 and 2000 g but at par with pearl pet jar of 500 g. The increase of larval density from 2 to 5 larvae to single pair of adult parasitoid in different

ovipositional chamber showed the distribution of egg laid which resulted in decreased parasitization, number of cocoons formed and sex ratio.

Storage of cocoons for 10 days at different test temperatures did not affected adult emergence significantly and emergence ranged from 95.96 to 97.58 per cent. Adult emergence decreased gradually with the increase of storage especially at low temperature (5°C). The sex ratio obtained from the emerged adult showed that low temperature (5°C) significantly affects the sex ratio. Highest sex ratio, 0.85, and maximum cocoons (47.08) were observed when cocoons stored for 10 days at 20°C while 5°C temperature inhibited the growth and development with least number of cocoons.

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1. INTRODUCTION

Maize is an important cereal crop which is cultivated in about 140 million hectares mainly in tropical and subtropical regions of which, approximately 96 m ha area is in the developing countries of the world. Although 68 per cent of global maize area is in the developing countries, which contributes to only 46 per cent of the world’s maize production. Low average yields of maize in the developing countries are responsible for the wide gap between the global share of area and share of

production. The average maize yield in the developed countries is more than 8 t / ha, while in the developing countries it is around 3 t / ha (Zaidi and Singh, 2005).

In India, maize is cultivated in 7 m ha with 20 m tones production during 2010-11 (Business standard, 2011). Rajasthan ranks first in the country in respect of area with 10.50 lakh ha and production of 19.54 lakh tones (Govt. of Rajasthan, 2008). Often the yield realized by the farmers is much less than the potential of the crop. Inspite of taking due care of the production component, at time the insect pests take a heavy toll to the crop thus bringing crop yield very low.

Maize is attacked by over 250 species of insect and pests (Mathur, 1991). Of those four species of tissue borers *viz*., maize stem borer or spotted stem borer (*Chilo partellus* Swinhoe), pink stem borer (*Sesamia inference*), shoot fly (*Atherigona soccata*) and Asiatic corn borer (*Ostrinia furnacalis* Guenee) are regular and serious pests of maize. Among these, maize stem borer, *C. partellus*, is the principal pest in all maize growing countries. It also attacks sorghum, millets, rice, sugarcane, bajra and other graminicious grasses. It is widely distributed in tropical Asia (India, Pakistan, Bangladesh, Afghanistan, Nepal, Cambodia, Indonesia, Laos, Sri Lanka, Thailand, Vietnam, Iraq, Japan, Nyasaland and Taiwan). Asian region is probably the native place for this pest.

Maize stem borer injury to maize includes leaf feeding, tunneling within stalk, disruption of the flow of nutrients to the ear, and subsequent development of “dead hearts” by damage to the central growing shoot of young plant. The first symptoms of *C. partellus* damage are the appearance of “shot hole” injury to whorl leaves. Plants that survive the initial attack show reduced inter-nodal length resulting in shoot ‘rosetting’. Yield loss is attributed the physiological effects on final ear size, lodging or the complete loss of ears and formation of “dead hearts” (Kfir *et al.* 2002).

Potential losses due to insect pests in maize on global basis is estimated to be of 14-18 per cent (Oerka, 2002), which is 52 million tons valued at $ 5.7 billion annually (James, 2003), while yield loss estimates for maize stem borer vary greatly depending upon the country, season, maize variety and fertilization (Kfir *et al*. 2002, De Groote *et al.* 2003). However, in studies with *C. partellus* alone, yields in east Africa were reduced by 15-45 per cent (Seshu Reddy and Sum, 1992). In South Africa, yield losses in maize and sorghum have exceeded 50 per cent (Kfir *et al.* 2002). The yield losses in maize by *C. partellus* reported by earlier workers in India were estimated to the tune of 5.14 to 91.22 per cent (Reddy, 1968, Chatterji *et al*.,

1969, Singh and Sajjan, 1982). At the lower limit of 25 per cent, the average loss in maize in the *kharif* season at a conservative estimate, comes to Rs. 1105 million annually (Siddiqui and Marwaha, 1994). The development of newer and resistant maize varieties play an important role in reduction of yield losses which are developed for their resistance through artificial release technique under field conditions against maize stem borer.

The existed Leaf Injury Rating (1-9) is being widely used to screen the germplasms against *C. partellus* and then to group them according to resistant potential which only considers different damage parameters like holes on leaf and stem and dead hearts up to 45-50 days. It is required to establish a correlation between different damage parameters by *C. partellus* and maize yield loss. The proposed LIR is in the need of verification after introduction of single cross hybrids across the country. Therefore, it was planned to investigate the correlation of damage symptoms *viz*., LIR with plant height, tunnel number, tunnel length and yield and plant height with tunnel number, tunnel length and yield and tunnel number with tunnel length and yield and tunnel length with yield.

So far no systematic work has been done on the relationship between damage symptoms and its impact on the grain yield. Therefore, present investigation was planned to correlate the different damage parameters with yield using HQPM-1 (moderate resistant cultivars) and African tall (susceptible cultivars) of maize.

Maize stem borer is a preferred host for many bioagents. In nature several natural enemies helps to regulate the population of maize stem borer, which are effective, non-disruptive to the ecosystem and relatively permanent.

Among the natural enemies about a dozen species of insect parasitoids have been recorded attacking immature stages of *C. partellus* from different parts of the country (Panwar, 2005), of which *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) is important one. It is a gregarious endo larval parasitoid of graminaceous stemborers. It is found in the nature during *kharif* season throughout the country and proven as a dominant larval parasitoid of *C. partellus* by reducing the population up to 32-55 per cent (Divyal *et al*., 2009, Kfir *et al.*, 2002, Padmaja and Prabhakar, 2004, Khambadkar *et al.*, 2003). The cycle of *C. flavipes* lasts approximately 22 days and 40 parasitoids develop in each host larva. The females of *C. flavipes* deposit multiple eggs in the host's body cavity (Overholt *et al.*, 1994) The adult life span of *C. flavipes* is quite short, approximately 34 hours at 25ºC

temperature, if adults are not fed. Because of the short life span, *C. flavipes* must mate quickly after emergence and begin searching for hosts (Mohyuddin and Inayatullah, 1981). Every parasitoid requires specific size and age of host for oviposition for more offspring, better survival and avoiding competition for food and space. It is essential to know the preferred larval stage and suitability of *C. partellus* for parasitism by *C. flavipes.*

The multiplication of larval parasitoid in laboratory is being achieved through individual and mass exposure method. The effect of space on parasitization is taken care during the provision of number of host larvae and parasitoids to avoid overcrowding. It is essential to isolate the parasitized larvae to avoid the super parasitization because over exposure of the host create the competition for food and space among the offspring and thus destroy the egg laying potential of parasitoid. Therefore, it was planned to investigate the optimum space required by *C. flavipes* for parasitization individually and in mass exposure method.

The short life span and over lapping generation helps *C. flavipes* to be more successful in the maize crop. Due to its important role in management of *C. partellus*, efforts have been done to augment the parasitoid in the maize ecosystem also (Jalali and Singh, 2003). Storage of cocoons of *C. flavipes* at low temperature is an essential prerequisite without altering their fitness (i.e., the preservation of the quality of the founder colony). Low temperature retards the development of parasitoids so as to synchronize their emergence in large numbers for augmentation during the availability of vunrable stage of the host in the fields. It was therefore, planned to investigate the effect of temperature on the adult development during storage.

A lot of work has been done on the biology and release of parasitoids but no systematic work has been carried out on the most preferred age of host larvae, optimum space required for parasitization and optimum temperature for storage of cocoons to meet out the demand during growing season. Therefore, the present investigations were conducted with following objectives:

1. To establish a correlation between damage symptoms on maize by *C. partellus* and maize yield.
2. To standardize the multiplication technique of *C. flavipes.*
   (a) To find out the preferred host larval age for maximum offspring's of *C. flavipes*.

(b) Investigation on requirement of space for parasitization.

3. To investigate the effect of low storage temperature on the efficiency of C. *flavipes.*

2. REVIEW OF LITERATURE

The present investigation was carried out to study the "Damaging potential of *Chilo partellus* Swinhoe and standardization of multiplication technique of *Cotesia flavipes* Cameron in Southern Rajasthan". The pertinent literature in relation to the proposed work is reviewed under the following sub heads:

1. Correlation between damage symptoms of maize by maize stem borer and maize grain yield.
2. Multiplication technique of *C. flavipes*:
   Effect of larval age and space of ovipositional chamber on multiplication of *C. flavipes.*
3. Effect of low temperature storage on the efficiency of *C. flavipes*

2.1 Correlation between damage symptoms of *C. partellus* and maize grain yield

Maize germplasms were tested under field conditions for resistance to *C. partellus* by introducing 25-30 black head stage eggs of maize stalk borer into the whorls of 15-19 days old plants and data on various biological parameters *viz.*, per cent incidence, per cent dead hearts, leaf injury scale including dead hearts were recorded (Singh *et al.,* 1962; Kalode and Pant, 1966; Singh *et al.,* 1968; Chatterji *et al.,* 1970; Sarup *et al.,* 1978; Panwar *et al.,* 1979 and Reddy, 2003). Sarup *et al.* (1977) reported that increase in the LIR (Leaf Injury Rating) significantly decreased the maize grain yield.

Kumar (1994) reported that artificial infestation of maize plants of Kenyan varieties with maize stem borer displayed a moderate level of resistance in terms of stem tunnelling and grain damage. Kumar and Asino (1994) reported that regression of grain yield on stem tunneling had negative relationship across maize genotypes. Grain yield of maize was also influenced negatively with the damage caused by *C. partellus* directly to the kernels.

Cardwell *et al.* (1997) calculated maize cob weight loss of 9 g per plant by borer infestation. At that time, the average plant loss from dead hearts across zones was 11 per cent.

Kumar (1997a) measured relationship among certain damage parameters and infestation of *C. partellus* in four maize genotypes both under natural and an artificial

infestation conditions. A highly significant correlation was observed between number of holes and stem tunneling (expressed as the absolute tunnel length or the percentage of stem length tunneled) by *C. partellus.*

Kumar (1997b) worked out the difference between extent of damage caused by *C. partellus* under artificial infestation and field conditions in five genotypes *viz*., Inbred A (susceptible), Mp704, Poza Rica 7832, MBR-Fam. 37 and ER-29SVR. He recorded higher infestation in terms of leaf feeding, stem tunneling and dead hearts under screen house. However, the relative difference among the genotypes was consistent both under screen house and field conditions.

Songa *et al.* (2001) reported that *C. partellus* damage greatly reduced maize grain yield, with tunnel length greater than 20 cm caused a 40 per cent reduction in potential yield. A 33 per cent yield loss was found in plants with more than one stem borer exit hole. Each stem borer hole was correlated with a 8-10 per cent yield loss. Good plant physical characteristics significantly increased grain yield. Principal component analysis showed that stem borer damage, plant height and stem diameter were key factors affecting maize grain yield. Regression analysis indicated that one cm of stem borer tunnel reduced yield by 3g / plant. Multiple regression analysis implied a 13.3 ± 1.5 g yield loss (8-10 per cent of potential yield) due to the damage of a single stem borer.

Kakar *et al.* (2003) conducted an experiment on four varieties of maize *i.e.* Local, Sadaf, Sultan and Akbar for resistance against *C. partellus*. Significant differences were found among genotypes regarding per cent infestation, dead hearts, weight of stalks and grains. Sultan proved to be the most tolerant variety while Local was least tolerant variety.

Arabjafari and Jalali (2007) reported positive correlation between leaf injury score caused by *C. partellus* and stem diameter of maize. While, negative correlation was found between leaf injury score and internodal distance.

Jindal and Hari (2008) correlated LIR with tunnel length in five germplasms namely CML 67, CM 500, DMH 1, JH 3459 and Basi local. They reported that CM 500 was graded with minimum LIR 3.99 ± 0.12 and tunnel length 3.97 ± 0.16 cm whereas Basi Local was considered with maximum LIR 6.39 ± 0.46 and tunnel length 7.27 ± 0.67 cm.

Belay and Foster (2010) studied on habitat management techniques to control maize stem borers in eastern and western Ethiopia. They reported positive correlation

between plant yields and plant height and diameter ($r = 0.65$, $P < 0.0001$ and $r = 0.68$, $P < 0.0001$, respectively). Cob damage (per cent) was positively correlated to tunnel length, number of holes and borer holes or larvae per plant ($r = 0.33$, $P = <0.0001$, $r = 0.21$, $P = <0.0001$ and $r = 0.69$, $P = <0.0001$, respectively). Mean internode damage (per cent) was also positively correlated with borers per plant ($r = 0.42$, $P = <0.0001$).

2.2 Effect of larval age and space of ovipositional chambers on multiplication of *Cotesia flavipes* Cameron

Cotesia flavipes Cameron (Hymenoptera: Braconidae) is a gregarious endo larval parasitoid of graminaceous stem borers. It is found in the nature during entire *kharif* season in maize growing areas across the country and play significant role in the management of maize stem borer population.

Campos Farinha *et al.,* (1998a) studied the effect of multiple mating on the number of layings, offsprings and sex ratio of *C. flavipes* that emerge from *Diatraea saccharalis* (F.). They found that parasitoid females were mostly monogamic and preferred to lay a batch of eggs once. The number of eggs laid, the offspring, sex ratio and the number of nonviable larvae produced by parasitoid that mated with one and two males were similar, even when variable number of layings occurred. Results suggest that a second mating does not influence parasitoid fitness.

Campos Farinha *et al.* (1998b) also observed that when *C. flavipes* females mated to one and two males were allowed to parasitize *D. saccharalis* larva, no interference or competitions between them were observed suggesting that this species avoids superparasitizing.

Campos Farinha and Chaud Netto (2000) studied the reproductive biology of *C. flavipes*. They exposed third to fifth instar *D. saccharalis* larvae individually to *C. flavipes* and recorded weight of parasitized larvae, number of egg layings, number of emerged parasitoids and their sex ratio. The number of egg layings of the parasitoid females did not vary according to host age, but the number of offspring was greater in heavier larvae. Sex ratio was biased towards females in all three, mainly when they received one, two and four egg layings. Although the number of males usually exceeds that of females in superparasitized larvae, results with self super parasitized larvae producing more females suggest that the females were not able to recognize hosts that were already parasitized by themselves. Then further investigated the

discrimination between parasitized and unparasitized larvae of *D. saccharalis*, developmental time and sex ratio of the parasitoids. Fifth instar larvae were used in the experiment. Three types of larvae unparasitized, recently parasitized and parasitized 24, 48 and 72 hours before exposure were offered to the females of *C. flavipes*. At first, females of *C. flavipes* could recognize parasitized larvae only until 24 hrs after previous parasitism. However, the sex ratio analysis indicated that the females laid more eggs than produced males in superparasitized hosts, suggesting that they can also distinguish parasitized larvae few days after the first parasitism. There was no significant difference on the mean number of eggs per host, considering the larvae parasitized only once and larvae superparasitized. The developmental periods of the parasitoids which emerged from the hosts of those two experimental groups did not differ. The viability of the parasitoids which developed in superpasitized hosts was lower than that recorded for the parasitoids which emerged from hosts parasitized only once (Campos Farinha *et al*., 2000).

Tillman (2001) studied the parasitization by *Cotesia marginiventris* (Cresson) on *Spodoptera exigua* (Hubner), as well as its sex ratio. Highest parasitization occurred when adult female parasitoids were closely associated with hosts. Percentage of female progeny was higher when females were closely associated with second instars.

Jalali and Singh (2002) studied selection and host age preference by natural enemies of *C. partellus*. They reported that *C. flavipes*, parasitized larvae that were in 2^{nd} to 6^{th} instar with significantly more parasitism, fecundity and shortest developmental period was recorded in 4^{th} and 5^{th} instar larvae. The correlation analysis showed significant positive relationship between age of larvae and number of cocoons obtained and per cent female progeny. The regression analysis showed that it was possible to predict number of cocoons based on larval instar parasitized. The results indicated that host age might be a primary factor in determining effectiveness of a parasitoid.

Shi *et al.* (2002) studied parasitism of larvae of different host instars and four development ages of fourth instar of diamond back moth by *C. plutellae.* The effects of host instar at initial parasitization on the development, survival, size and fecundity of the parasitoid were determined in the laboratory at 25°C temperature, while effects of parasitism on host development and food consumption were investigated at 28°C. *C. plutellae* could parasitize larvae of all four instars of *Plutella xylostella*, but

preferred 2nd and 3rd instars. In a choice test, the relative parasitism indices for 2nd, 3rd and 4th instars were 0.37, 0.39 and 0.24, respectively. Parasitism decreased sharply with increasing host age in the 4th instar and approached zero in host larvae that had gone beyond 37 per cent of 4th stadium. The development time and the final adult size of the parasitoid varied with the host instar at initial parasitization. Parasitoids with initial parasitism in the 4th instar hosts had the shortest development time, followed by those in the 3rd instar, and then by those in the 2nd instar. Parasitoids starting parasitism in 2nd instar hosts were smaller in body size than those starting in the 3rd or 4th instar. However, resultant females starting parasitism in 3rd instar hosts had the highest fecundity. Parasitized larvae exhibited longer development time and increased food consumption compared with unparasitized ones.

Shekharappa and Kulkarni (2003) observed that the third instar larvae of *C. partellus* were most suitable for parasitization by *C. flavipes*.

Karamaouna and Copland (2009) studied on fitness and life table parameters of two endoparasitoids of the obscure mealybug, *Pseudococcus viburni* (Signoret), the solitary, *Leptomastix epona* (Walker) and the gregarious, *Pseudophycus flavidulus* (Brèthes), were examined in relation to host size with a view to determine the efficacy of the parasitoids as biocontrol agents of the pest. Two host size classes (small, which mostly comprised third instar nymphs and large, which consisted of female adults) were studied. Both parasitoids achieved a greater intrinsic rate of natural increase and gross reproductive rate in addition to a shorter generation and doubling time in large mealybugs compared with small ones. Consequently, large hosts are expected to have a higher impact on the rise of the parasitoid population and the potential of the parasitoids to control the mealybug population.

2.3 Effect of storage temperature on parasitization efficiency, sex ratio and progeny production of *C. flavipes*

Singh (1997) reported that 7 days old eggs of lepidopterons parasitized by *Trichogramma chilonis* could be stored for 20 days in the refrigerator without adversely affecting the adult emergence, their parasitization efficiency and sex ratio. Similarly Khosa and Brar (2000) reported that *T. chilonis* could be stored in the refrigerator and successfully utilized for 23 days without adversely effecting their emergence and parasitization efficiency. The mean per cent parasitization decreased with the increase in storage period.

Mbapila and Overholt (2001) studied the effect of temperature on the development, longevity and population growth of *C. flavipes* and *C. sesamiae*. They reported that the development of both *Cotesia* spp. from oviposition to cocoon formation and adult emergence was inversely related to temperature. The longevity of the parasitoids was also inversely related to temperature. The mean number of females and total adult progeny produced by *C. flavipes* on two host species were, in most cases, higher than *C. sesamiae*.

Getu *et al.* (2004) investigated the effect of temperature and relative humidity on life table parameters of two populations of *C. flavipes*. The results indicated that both the factors and their interactions significantly affected the population growth of *C. flavipes*. The intrinsic rate of increase of the North Pakistan population of *C. flavipes* was higher than that of the Indian population at all humidities at 28°C temperature, but there were no differences at other temperatures or humidities.

Jiang *et al.* (2004) examined the survival, development parameters and body growth patterns of host and its parasitoid at different temperatures (22, 26 and 30ºC) using third and fourth instars of *C. partellus*. For non-parasitized hosts, larval mortality tended to be highest at lowest temperature and for parasitized at third host instars only at highest temperature. Development time of *C. flavipes* immatures significantly decreased with host instar and with temperature. Sex ratio of *C. flavipes* varied from male to female biased with increase in temperature. The increase in body weight of parasitized fourth instar *C. partellus* was higher than in non-parasitized larvae at all temperatures. Parasitism by *C. flavipes* has no effect on the food uptake by *C. partellus*, but significantly less food was consumed by both parasitized and non parasitized larvae at 26ºC temperature.

Saskya Van Nouhuys and Guangchun Lei (2004) studied the strength of interaction between the parasitoid *C. melitaearum* and the host *Melitaea cinxia*. They reported that interaction was influenced by early spring temperature, which affected parasitoid development differently than the development of the host. At cool air temperatures, the dark-coloured and mobile host larvae benefit from basking in the sun, while the white and immobile parasitoid cocoons developed slowly in shaded microclimates, became adults after hosts have pupated and were no longer available for parasitism. At warm temperatures many adult wasps emerged in time to parasitize host larvae.

Tanwar (2004) conducted an experiment on variability and reproductive compatibility among populations of *C. flavipes* from different agro-climatic conditions. He reported that no population of *C. flavipes* was tolerant to low temperature, as parasitism by all populations remained significantly low at 15ºC compared to 25ºC.

Bayrama *et al*. (2005) studied effect of cold storage on the pupae and adults of *Telenomus busseolae* Gahan. Firstly, the effect of storage at three temperatures (4, 8 and 12 ± 1°C) and seven time durations (1, 2, 4, 6, 8, 10 and 12 weeks) was evaluated. Laboratory performance of emerged parasitoids was measured and compared to that of the unstored parasitoids. Storage temperature had a significant adverse effect on adult emergence. *T. busseolae* could be stored for 4 weeks at 4 and 8 ± 1°C but only 2 weeks storage was possible at 12 ± 1°C. Furthermore, mean percentage parasitism of host eggs by emerged parasitoids was reduced and F1 progeny sex ratio of the parasitoid became more male biased with increasing length of storage treatments. There was no effect of cold storage on the mean adult emergence of F1 progeny. Similar experiment on the effect of low temperature (4 ± 0.5ºC) and refrigerator storage on three trichogrammatids, *viz*., *Trichogramma chilonis*, *T. pretiosum* and *T. brasiliense* under laboratory condition was conducted by Parminder Kumar *et al*. (2005). *T. chilonis* and *T. pretiosum* can be stored for 20 days whereas *T. brasiliense* for 10 days without adversely affecting their emergence and parasitisation efficiency taking 60 per cent emergence and 60 per cent parasitism as standard. The emergence in *T. brasiliense* was zero after 34 days of storage whereas 20.3 per cent was recorded in *T. chilonis* and 15.7 per cent in *T. pretiosum* after 60 days of storage. *T. chilonis* showed the highest emergence and parasitization efficiency followed by *T. pretiosum* and *T. brasilience*.

Luczynski *et al.* (2007) determined the influence of low temperature and the duration of exposure on development and mortality of *Encarsia formosa* during storage and on the pattern of emergence of adults. Adult emergence was prevented at temperatures below 10°C although the pupae continued to develop even at 4°C. They found all three fitness parameters declined with increased duration of cold storage and its harmful effects accumulated and increased over time.

Carvalho *et al*. (2008) evaluated the effect of low temperature in stored cocoons of *C. flavipes*. They found that the storage of pupae of *C. flavipes* in

refrigerator temperature for 5 days does not affect its development and the stored generation.

Chen *et al.* (2008) determined the effects of cold storage on the survival, development and reproduction of parasitoid, *Gonatocerus ashmeadi* (Hymenoptera: Mymaridae). Immature wasps were stored for 20 days within the host without reducing their subsequent survival, development or progeny fitness parameters. After 30 days of storage, survival declined, post storage developmental time was extended, and the fecundity of the adult females decreased.

Hackermann *et al.* (2008) studied the performance of cold stored and unstored parasitoid *Hyssopus pallidus* (Askew) after release at different temperature regimes in the laboratory at the level of two subsequent generations. Cold storage for 14 days at 4°C imposed to the pupal stage of the parasitoid did not reduce the parasitism capacity of the parental generation, nor did it alter the female biased sex ratio of the progeny. Furthermore, offspring number was only reduced after release at low ambient temperatures, but not at 25°C and 30°C temperature. Irrespective of whether the parasitoids originated from the stored or unstored group, highest parasitism rate was achieved at temperatures above 20°C. In conclusion, *H. pallidus* can be cold stored for short periods without any measurable quality loss after release at most except at low ambient temperatures.

Hailemichael *et al.* (2008) reported that three species of *Cotesia* namely *C. sesamiae, C. flavipes* and *C. chilonis* attacked on larvae of *Sesamia calamistis* and successfully developed in 2^{nd} to 6^{th} larval instar but parasitoid-induced mortality was highest on second instars. On most instars, *C. sesamiae* and *C. flavipes* produced larger broods than *C. chilonis*. However, across temperatures, *C. flavipes* yielded the highest number of offspring, followed by *C. sesamiae* and *C. chilonis*. The sex ratios did not vary significantly with species and temperature. Thus, the reproductive potentials of *C. sesamiae* and *C. flavipes* were greater than that of *C. chilonis*.

Fatima *et al.* (2009) observed that the combination of irradiation and low temperature (10°C) proved effective for prolonged storage of *C. flavipes.* They found that pupae of *C. flavipes* irradiated at 20 Gy could be stored for 2 months at 10°C temperature without apparent loss of quality and deferred emergence by 29-30 days.

Foerster and Foerster (2009) investigated the effect of five constant temperatures between 14 and 30°C on the development time and adult emergence of five *Trichogramma* species. Host eggs were parasitized at 20°C and then transferred

to the study temperatures to follow development and emergence of parasitoids. All five species were able to develop and emerge within the range of temperatures evaluated, and the effect of temperature on development rates could be described by linear regression. *T. acacioi* and *T. rojasi* were the most cold-tolerant species, with lower threshold temperatures of 8.1 ± 0.16°C and 9.2 ± 0.16°C, respectively. *T. atopovirilia* was the least cold-adapted species, with a lower threshold of 10.2 ± 0.13°C. Degree-day accumulation ranged from 153.8 DD for *T. atopovirilia* to 190.7 DD for *T. acacioi*. Adult emergence was higher than 90% for *T. atopovirilia* and *T. pretiosum* at all temperatures, whereas *T. lasallei* emergence dropped to 71.3 per cent at 14°C and to 58.3 per cent at 26°C, both significantly lower than the emergence of *T. pretiosum* and *T. atopovirilia*. Significantly less *T. acacioi* adults emerged at 30°C than either *T. pretiosum* or *T. atopovirilia*. The sex-ratio was not affected within the range of temperatures studied, and varied from 0.65 to 0.88 [female / (male + female)]. Differences among *Trichogramma* spp. densities in the field can be attributed to slower development rates and/or reduced emergence of adults, both at low and high temperatures.

Karamaouna and Copland (2009) studied on fitness and life table parameters of two endoparasitoids of the obscure mealybug *Pseudococcus viburni* (Signoret), the solitary *Leptomastix epona* (Walker) and the gregarious *Pseudaphycus flavidulus* (Brethes), were examined in relation to temperature with a view to determine the efficacy of the parasitoids as biocontrol agents of the pest. Three temperature levels (21°C, 26°C and 31°C) were studied. The lower developmental threshold and thermal constant of the host and the parasitoids were found similar so the coincidence of pest and parasitoids is likely. The rate of development of the parasitoids increased with a linear trend as the temperature increased from 21°C to 31°C. Temperature had a significant effect on mummification in both parasitoid species and on successful parasitism by *P. flavidulus*.

Pereira *et al.* (2009) studied the development of parasitoid *Palmistichus elaeisis* Delvare on previously refrigerated pupae of *Bombyx mori* L. Forty-eight to seventy two hours-old pupae of *B. mori* were stored at 10ºC for 5, 10, 15 and 20 days and then exposed to parasitism by *P. elaeisis* females. This parasitoid showed shorter duration of the life cycle when reared on pupae of *B. mori* which were previously stored at 10ºC during 15 days. *P. elaeisis* parasitized 100 per cent of the pupae of *B. mori* after storage at 10ºC during all periods with emergence of this parasitoid from

78 to 100 per cent of these pupae. *P. elaeisis* had a higher number of progeny per pupa of *B. mori* stored for 15 days at 10ºC. Pupae of *B. mori* can be stored for 15 days at 10ºC before being used to rear *P. elaeisis.*

Regiane Cristina *et al.* (2009) studied biological characteristics and thermal requirements of new strain *Trichogramma pretiosum*, in Brazil, and designated as *T. pretiosum* RV. The parasitoid was reared on eggs of *Pseudoplusia includens* and *Anticarsia gemmatalis* at different constant temperatures within an 18-32°C temperature range. The number of annual generations of the parasitoid was also estimated at those temperatures. Results showed that *T. pretiosum* developmental time from egg to adult was influenced by all temperatures tested within the range, varying from 6.8 to 20.3 days and 6.0 to 17.0 days on eggs of *P. includens* and *A. gemmatalis*, respectively. The emergence of *T. pretiosum* from eggs of *A. gemmatalis* was higher than 94 per cent at all temperatures tested. When this variable was evaluated on eggs of *P. includens*, however, the figures were higher than that within the 18–30 °C range (more than 98%), and were also statistically higher than the emergence observed at 32 °C (90.2%). The sex ratio of the parasitoids emerged from eggs of *A. gemmatalis* decreased from 0.55 to 0.29 at 18-32°C, respectively. However, for those emerged from eggs of *P. includens*, the sex ratio was similar (0.73, 0.72 and 0.71) at 20, 28 and 32 °C, respectively. The lower temperature threshold (*Tb*) and thermal constant (*K*) were 10.65 °C and 151.25 degree-days when the parasitoid was reared on eggs of *P. includens*; and 11.64 °C and 127.60 degree-days when reared on eggs of *A. gemmatalis* respectively. The number of generations per month increased from 1.45 to 4.23 and from 1.49 to 4.79 when the parasitoid was reared on eggs of *P. includens* and *A. gemmatalis*, respectively, following the increases in the temperature.

3. MATERIALS AND METHODS

The present study entitled, "Investigations on damaging potential of *Chilo partellus* Swinhoe and standardization of multiplication technique of *Cotesia flavipes* Cameron in Southern Rajasthan" was carried out at the Instructional Farm and Maize Entomology Laboratory, Department of Entomology of Rajasthan College of Agriculture, Udaipur, Rajasthan during *kharif* 2008 and 2009. The materials used and methodologies adopted on various aspects of the studies have been presented here under:

3.1 Climatic condition of the location

The zone has a typical sub-tropical climatic condition characterized by mild winters and moderate summers associated with high humidity especially during July to September. The average annual rainfall of this tract ranges between 450 and 650 mm, most of which is contributed by southwest monsoon from July to September with occasional rain during the winter season. During summers, the temperatures may go as high as 45.5°C, while in winters it may fall as low as 4.5°C. This region provides a safe and long growing season for most of the crops.

3.2 Experimental details

The experimental field was prepared during the last week of June by ploughing with the help of disc plough followed by cross harrowing and planking. A well pulverized field was obtained for sowing the crop. Recommended doses of nitrogen and phosphorus (80 kg N and 60 kg P_2O_5) were applied to the crop. One third dose of the nitrogen and full dose of phosphatic fertilizer was applied at the time of sowing through DAP and Urea, while remaining dose of nitrogen was applied at tasseling stage in equal amount. To protect the crop from weeds atrazine was applied @ 0.5 kg / ha immediate after sowing followed with weeding at two hoeing and weeding followed by earthing was done at 20 and 30 days after sowing.

3.3 Determination of correlation between damage symptoms of maize by maize stem borer and maize yield

The screening of maize cultivars against maize stem borer is done with release of 15-20 eggs per plant at 12-16 days after sowing but the different egg parasitoids present naturally destroy the eggs by parasitization. Therefore, in the present investigation neonate larvae were released. The released larvae started feeding

and led to different type of infestation symptoms like scrapping of chlorophyll from leaves, window hole / spiral holes in leaves, holes in stems and dead hearts which are described by LIR (1-9) scale. The proposed investigation was conducted with single cross hybrid moderate resistant variety (HQPM-1) and composite susceptible variety (African tall).

Different numbers of larvae (4, 8, 12, 16, 20, 24, 28 and 32) were released on plant of HQPM-1 and African tall at 14-16 days after germination to achieve all categories of Leaf Injury Rating (1-9). The experiment was sown at 60 × 60 and 25 × 25 cm row to row and plant to plant spacing on 16th July and 8th July in 2008 and 2009 respectively. There were 12 plants in each row and only 10 plants were selected for recording the data. Two rows with four replications were sown for every infestation dose. Thus eighty plants were taken in consideration for observations of each infestation level. One row was kept fallow after every two rows. The experiment was therefore, planned with 8 treatments. After one month of release of neonate larvae of maize stem borer Leaf Injury Rating (1-9) was recorded. Further, plant height up to tassel base, tunnel length, tunnel numbers and yield were recorded at 14 per cent moisture. Tunnel number and tunnel length were recorded after splitting of individual plant. The data recorded on moderate resistant and susceptible cultivars were analyzed by randomized block design with eight treatments and four replications (Plate 1 & 2).

Following formula was used for calculating correlation coefficient:

$$r_{xy} = \frac{\sum xy - \frac{(\sum x)(\sum y)}{n}}{\sqrt{\left[\sum x^2 - \frac{(\sum x)^2}{n}\right]\left[\sum y^2 - \frac{(\sum y)^2}{n}\right]}}$$

Where,

r_{xy}	=	Simple correlation coefficient
x	=	Independent variable (LIR, plant height, tunnel number and tunnel length)
y	=	Dependent variable (yield)
n	=	Number of paired observations

The rating of individual plant of each plot was done after one month of the release of larvae on the basis of 1-9 scale described by Chatterji *et al*. (1970) as given below.

Table 1. Leaf Injury Rating description

LIR	Damaging symptoms on maize plant
1	Apparently healthy plant.
2	Plants showing slightest damage on leaf or few pin holes on one to two leaves.
3	Plants showing more pin holes or shot hole in three to four leaves.
4	Plants showing injury (pin holes, shot holes and slits) in about one third of the total number of leaves and mid-rib tunneling on one or two leaves, if any.
5	Plants showing 50 per cent leaf damage (pin holes, shot holes, slits and streaks) and mid-rib damage, if any.
6	Plants showing varied type of leaf injury in about two third of total number of leaves.
7	Plants with every type of leaf injury and almost all the leaves damaged.
8	Plants showing maximum leaf injury and likely to form “dead heart” (such plants usually show stunted growth.
9	Plants showing “dead heart”.

3.4 Rearing of maize stem borer

The mass rearing of maize stem borer, *C. partelllus* is essential to obtain the required number of egg masses and larvae of different instars for the experiments and for artificial infestation to maintain uniform pest infestation in the crop during the investigation. Therefore, the rearing of *C. partellus* was done on natural food (maize stem).

In order to have a continuous supply of egg masses and larvae of *C. partellus*, a large number of infested stems of previous maize crop were collected from the fields at the time of harvest. These stems were brought to the laboratory and kept up to last week of April. The stems were then splitted open, hibernating larvae were collected and kept in big glass jars of size 20 × 15 cm and also in wooden boxes provided with layers of blotting paper for better pupation. The pupae thus formed were collected and kept for adult emergence.

After emergence, the adults (male and female) were transferred into egg laying chambers lined with white rice paper for oviposition. Few strips of folded paper were placed inside the chambers to provide more area facilitating egg laying. Five cm deep layer of fine sand properly moistened to maintain the humidity in the ovipositional chamber (R.H. 70-80 per cent) was also laid at the bottom. A small cotton swab socked in 10 per cent sugar solution was kept inside the chamber in a small petridish to fulfill the adult's food requirement. The chambers were covered with white muslin cloth and held tightly with rubber bands to prevent the adult exit. These chambers were kept in culture room maintained at 27 ± 2° C and relative humidity 70 ± 5 per cent for egg laying. The eggs laid by the females on the paper were clipped off and healthy egg masses were released on the maize whorl kept in jars (20 × 15 cm^2) for hatching and feeding in early stage.

The food was thoroughly washed with water and excessive moisture was removed by placing them on blotting paper. The glass jars were rinsed with 1 per cent formaldehyde and dried. The food was changed at an interval of 2-3 days regularly till pupation taken place. Twenty five larvae were placed per jar and the larvae carefully handled with the help of camel's hair brush. To facilitate pupation 5 cm thick layer of washed and sterilized sandy soil covered with folding of blotting paper was placed at the bottom of each jar and full grown larvae were placed in it. The larvae pupated in blotting paper and maize stem piece, which were removed and placed in glass jars lined with blotting paper at the bottom and covered with muslin cloth to avail the emergence of adults. The moths after emergence were released in ovipositional chambers for further multiplication and maintenance of culture.

3.5 Rearing of *Cotesia flavipes* Cameron

Cotesia flavipes Cameron (Hymenoptera: Braconidae) is a gregarious endo parasitoid of graminaceous stem borers. They deposit about 40 eggs in host's body cavity. First instar parasitoid larvae eclose after about 3 days and begin feeding internally. *C. flavipes* develops through three larval instars in the host body, and then emerges from the host by chewing through the integument. The egg / larval period lasts about 14 days at 25°C.

After emergence from the host, the last instar larvae spin cocoons and pupate. Pupation takes about 6 days at 25°C, after which adult emerged. The adults are small wasps about 3-4 mm in length. Males and females can be differentiated by the length

of the antennae as males are having twice the length of the female antennae. The adult life span of *C. flavipes* is quite short, approximately 34 hours at 25°C if adults are not fed. Provision of a 20 per cent honey / water solution prolongs the lifespan to about 51 hours.

The multiplication of *C. flavipes* was done through individual exposure method. When parasitoids were ready to emerge from cocoons, placed in large sleeve cage (35 cm^2). A 20 per cent honey / water solution on cotton wool was provided in a petridish in the bottom of the cage for adult feeding. When parasitoids began to emerge, cage was placed under incandescent light for about 2 hours to stimulate feeding. Distilled water sprayed inside the cage through small hand sprayer to maintain the humidity. This cage was kept under incandescent light and started host exposure individually. To expose the host, individual larva was offered to parasitoids by holding in soft forceps inside the cage. Medium to large sized host larvae (4^{th} to 6^{th} instars) were used for exposure. *C. partellus* reared on natural diet was used directly for exposure. After parasitization larvae was placed in separate vial / container for rearing. Parasitization can be detected by closely watching the encounter between parasitoid and host. The parasitoid grasps the borer with her legs, bends the abdomen downward and forward, and inserts the ovipositor. At ovipositor insertion the larvae reacts violently and become quiescent. Oviposition generally occurs rapidly within about 5 seconds.

After oviposition larvae were removed immediately from the cage to avoid the superparasitization. The exposure was continued till the parasitoid except the hosts larvae for parasitization. The larvae were removed from the cage, placed in a glass jar 16×10 cm^2 with natural food. The maize pieces were changed at an interval of 2-3 days to avoid the fungal contamination. After 10-18 days of exposure, parasitoids exit the host larvae and immediately begin spinning cocoons. Once cocoons were completely formed, removed from the maize pieces and placed in clean vials. The process was continued till the culture multiplied and as and when required in the present investigation (Plate 3).

3.6 Preference of larval age for maximum offspring of *C. flavipes*

In the present investigation, the culture of *C. flavipes* was initiated from parasitized *C. partellus* larvae collected from maize fields, reared on *C. partellus* larvae and maintained in a temperature controlled room at 27 ± 2 °C and 75 ± 5

per cent relative humidity. The larvae of maize stem borer of different ages i.e. 5, 8, 11, 14, 17 and 20 days were taken from the culture and kept inside the glass tube (15 × 2.5 cm). The mated adult females of *C. flavipes* were selected and fed with 20 per cent sugar solution. One female adult parasitoid was released inside the glass tube for 24 hours exposure. After 24 hours parasitization, the larvae were separated and reared on splitted maize pieces. Each exposure was replicated 4 times with freshly mated adult parasitoids. The larvae after exposure were collected back and kept with splitted maize stubbles inside the BOD maintained at 27 °C and 75 per cent relative humidity for further multiplication. The observations on per cent parasitization, number of cocoons formed per larva and sex ratio were counted and analyzed through completely randomized design.

3.7 Effect of space on the efficiency of *C. flavipes*

The proposed investigation was conducted with the help of different sized ovipositional chambers. For this the test tube of 12 × 2.5 cm size and pearl pet plastic cage of different storage capacity *viz.*, 500g (11 × 8 cm^2), 1000g (16 × 10 cm^2) and 2000g (23 × 12 cm^2) were used in parasitization. Variable numbers of host larvae (1, 2, 3, 4 and 5) were exposed for 24 hours to one mated female of *C. flavipes* in individual exposure method and collected back for rearing on maize stem piece. Each set of experiment was replicated 5 times. Per cent parasitization, number of cocoons formed per larva and sex ratio after adult emergence were recorded and data were analyzed by completely randomized design.

3.8 Effect of low temperature on the efficiency of *C. flavipes* during storage

The effect of storage on the performance of *C. flavipes* was evaluated by measuring the different variables like per cent parasitization over 24 hrs (number of parasitized larvae / total number of larvae exposed), per cent emergence of F_1 progeny (number of emerged adults / total number of parasitized larvae) and the sex ratio of F_1 progeny (number of females / total number of individuals).

One hundred cocoons were kept in BOD for 30 days fixed at 5, 10, 15 and 20°C. Twenty cocoons were taken out regularly from 10 days onwards to 30 days at 5 days interval and stored in test tubes to record the per cent parasitization, adult emergence and sex ratio.

The 4th instar host larvae at a time were offered individually to 24 hours old mated female parasitoids at a ratio of one parasitoid per host in test tube (15 × 2.5 cm^2) which was closed with cotton plug. One small piece of fresh maize plant was kept in each glass tube. A droplet of diluted sugar water solution (1:5) served as food source for the female parasitoid. The female of *C. flavipes* removed from the vial 24 hours later. Each adult pair was utilized for five days for parasitization. Parasitized larvae were separated after 24 hrs and kept inside BOD fixed at 27 ± 2°C temperature and 70 ± 5 per cent RH until the formation of the parasitoid cocoons. The cocoons formed were counted, separated and kept in a glass vials for emergence of adults. The adult emerged were counted as per the male and female. The differentiation in the sex was made with the presence of different type of antennae in both sexes. The food (sugar and water solution at 1:5), was provided to emerged adults. The data recorded on number of cocoons formed and adult emerged with different sex ratio were analyzed through completely randomized design.

4. RESULTS

The investigations on correlation between damage symptoms in maize caused by *C. partellus* and yield of maize and standardization of multiplication technique of *C. flavipes* was conducted during *kharif* 2008 and 2009.

4.1 Correlation between damage symptoms by *C. partellus* and maize yield

In order to determine the correlation between damage symptoms and yield, two maize varieties namely HQPM-1 and African tall were used in the experiment to compare different parameters of study *viz*., LIR, plant height, tunnel number, tunnel length and yield.

The release of neonate larvae of maize stem borer on the maize plants of different varieties at susceptible stage, 12 to 16 days after germination, resulted in the varied degree of infestation to the plants (Plate 2). The severity of infestation symptoms vary from spiral holes to dead heart, reduction in plant height, increase in length and number of tunnels and decrease in yield. The data thus obtained on different damage symptoms are presented in Table 2 to 6 and depicted in Fig. 1a to 5b.

4.1.1Effect of release rate of *C. partellus* on damage potential (LIR) in maize

Artificial infestation of maize plants with 4, 8, 12, 16, 20, 24, 28 and 32 neonate larvae / plant of *C. partellus* resulted in variable degree of infestation which are presented in Table 2 and depicted in Fig. 1a and 1b.

4.1.1.1 HQPM-1:

The data on Leaf Injury Rating in HQPM-1during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly showed that all treatments differ significantly to each other in terms of damage symptoms. Highest Leaf Injury Rating 8.92 during 2008 was recorded in T_8 (32 larvae / plant) wherein all infested plants converted to dead hearts. Similarly in T_7 where 28 larvae / plant were released also gave complete dead heart symptoms. The intensity of infestation was severe even after release of 24 larvae / plant where most of the plants either converted to dead heart or a spiral holes in all leaves with slits and holes in stem. These types of infested plants were considered for 6.87 LIR. The release of 12, 16 and 20 larvae / plant also resulted in spiral holes on two third leaves and LIR recorded for them were 3.81, 4.89 and 5.81,

respectively. The lesser number of larvae, 4 and 8 larvae / plant, resulted in very less infestation and 1.64 and 2.80, respectively, LIR was recorded.

Similar results were obtained during 2009, the LIR among different release rate varied from 1.82 to 8.89. Highest (8.89) LIR was recorded with release of 32 larvae / plant whereas lowest 1.82, LIR was observed when 4 larvae / plant were released.

Pooled analysis of the two years data showed the similar trend, wherein release of 32 larvae / plant resulted in complete dead heart formation with 8.91 LIR followed by 7.96 with release of 28 larvae / plant. The release of 24, 20, 16 and 12 larvae / plant resulted in 6.81, 5.85, 4.87 and 3.87 LIR, respectively. The release of 4 and 8 larvae / plant resulted in to 1.73 and 2.79 LIR, respectively. It is also apparent from the Table (2) that all treatments differed significantly to each other.

4.1.1.2 African tall:

The data on Leaf Injury Rating in African tall during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly shows that intensity of infestation was very severe even after release of minimum number of larvae / plant. The infestation during 2008, differed significantly among T_1 to T_5 wherein 4.19, 5.36, 6.16, 6.94 and 7.59 LIR was recorded after release of 4, 8, 12, 16 and 20 larvae / plant, respectively. The LIR of 6.94 and 7.59 recorded in the infested plants with 16 and 20 larvae / plant also showed very high infestation in respect of all type of damage symptoms and was at par with T_6 to T_9. The gradual increase in LIR was observed with increase in number of larvae. It is also apparent from the Table (2) that increase of larvae to 24, 28 and 32 per plant resulted in very high LIR 8.93, 9.00 and 9.00, respectively and these treatments were found statistically at par.

Similar results were obtained during 2009. The highest LIR 9.00 was recorded with release rate of 28 and 32 larvae / plant followed by 8.95 after the release of 24 larvae / plant but these treatments were found statistically at par. The release of 16 and 20 larvae / plant also resulted higher LIR 7.66 and 8.37 respectively which were statistically different to T_6, T_7 and T_8 but infested plants were very close to dead hearts whereas lowest 4.28 LIR was observed with release of 4 larvae / plant.

Pooled analysis of the two years data showed the similar trend wherein release of 24, 28 and 32 larvae / plant resulted in severe infestation with 8.94, 9.00 and 9.00 LIR respectively. These treatments were statistically at par but different from treatments of T_1 to T_5. The release of 16 and 20 larvae / plant also resulted in severe

infestation and graded as 7.30 and 7.98 LIR, respectively. Release of 4 larvae / plant resulted in LIR of 4.23 while 8 and 12 larvae / plant exhibited LIR of 5.28 and 6.41, respectively.

4.1.2 Effect of release of *C. partellus* on plant height in maize

The data recorded on plant height of HQPM-1 and African tall after the infestation of *C. partellus* at different release rate are presented in Table 3 and depicted in Fig. 2a and 2b.

4.1.2.1 HQPM-1:

The data on plant height in HQPM-1 during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly show that plant height decreased with increase in the number of neonate larvae. It is visible from the Table 3 that longest plant height of 155.85 cm, was recorded with minimum number of larvae (4 larvae / plant) released, followed by 149.34, 132.94, 116.57 and 95.00 cm with 8, 12, 16 and 20 larvae / plant, respectively during 2008. The shortest height of 33.79 cm was observed with release of 32 larvae / plant followed by 46.63 cm with 28 larvae / plant respectively. The plant height of 95.00 and 89.74 cm was recorded with release of 20 and 24 larvae / plant, respectively which did not differ significantly and was found at par.

Similar results were obtained during 2009 by recording varied plant height, 31.52 to 152.95 cm. Longest plant height, 152.95, cm was recorded with release of 4 larvae / plant which was at par with 145.70 cm with release of 8 larvae / plant, whereas shortest (31.52 cm) plant height was observed with release of 32 larvae / plant. It is also clear from the data that release of 12, 16, 20, 24, 28 and 32 larvae / plant have marked difference in the plant height and recorded 134.87, 118.36, 92.97, 77.27, 47.42 and 31.52 cm plant height, respectively which differ significantly to each other.

Pooled analysis of the two years data showed the similar trend wherein release of 32 larvae / plant resulted in shortest plant height, 32.66 cm, with complete dead heart formation whereas release of 4 larvae / plant resulted in to 154.40 cm plant height. It is also apparent from Table 3 that all the treatments differed significantly to each other and there was gradual decrease in plant height with the increase in the number of larvae released.

4.1.2.2 African tall:

The data on plant height in African tall during 2008 and 2009 after release of neonate larvae of *C. partellus* (Table 3) clearly showed that reduction in plant height was very high with the increase of release rate of larvae. The data recorded during 2008 showed the longest plant height of 261.94 cm, with release of 4 larvae / plant followed by 259.99 and 239.21 cm with 8 and 12 larvae released per plant respectively but were statistically at par. The increase in the number of released larvae at 24, 28 and 32 per plant, drastically reduced the plant height being 26.78, 25.60 and 17.49 cm, respectively.

Similar results were obtained during 2009 wherein release of 4 larvae / plant resulted in longest plant height of 263.75 cm followed by 255.81 cm after release of 8 larvae / plant but statistically at par. The increase in the number of larvae as 12 and 16 per plant resulted in 211.17 and 167.08 cm plant height respectively and differed significantly. The release of larvae from 20 to 32 per plant reduced the plant height from 36.64 to 19.36 cm. The data showed the gradual reduction in plant height with release of 24, 28 and 32 larvae / plant but were statistically at par.

Pooled analysis of the two years data also showed the similar trend wherein release of 24, 28 and 32 larvae / plant resulted in minimum plant height and differed from all other treatments. The release of 4 and 8 larvae / plant resulted in longest plant height i.e. 262.85 and 257.90 cm, respectively which were at par with each other whereas release of 12, 16 and 20 larvae / plant resulted in gradual reduction in plant height i.e. 225.19, 178.30 and 85.54 cm, respectively and significantly differed from other treatments.

4.1.3 Effect of release rate of *C. partellus* on tunnel number in maize

The infestation of neonate larvae of *C. partellus* to maize plants after 12 to 16 DAG (Days After Germination) resulted in formation of tunnels inside the plants and caused huge yield loss. In the present investigation number of larvae from 4 to 32 per plant in HQPM-1 and African tall resulted in the varied number of tunnels which were quantified and presented in Table 4 and depicted in Fig. 3a and 3b.

4.1.3.1 HQPM-1:

The data recorded on tunnel number during 2008 (Table 4) showed that minimum release of 4 larvae per plant, resulted in less tunnel number (0.63 per plant) but gradually increased from 0.83 to 1.40 per plant with increase in number of larvae

released from 8 to 24 larvae / plant. The release of larvae at 8, 12, 16 and 20 per plant did not have significant difference among each other and resulted tunnel numbers were at par. It is also apparent from the Table 4 that minimum tunnel number, 0.06 per plant was observed after the release of 32 larvae / plant followed by 0.31 cm per plant with 28 larvae / plant due to complete conversion of plants in dead hearts.

Similarly the data recorded during 2009 showed (Table 4) that minimum release of 4 larvae per plant, resulted in less tunnel, 0.59 per plant, but gradually increased from 0.85 to 1.33 per plant with increase in larval number from 8 to 24 larvae / plant. The release larvae at 8, 12 and 16 per plant did not have significant difference among each other and resulted tunnel numbers were at par. The release of maximum number of larvae, 32 per plant, resulted in minimum tunnel number, 0.03 per plant followed by 0.33 per plant with 28 larvae / plant.

Pooled analysis of the two years data showed the similar trend wherein release of 24 larvae / plant resulted in maximum tunnel number, 1.36 per plant whereas release of 28 and 32 larvae / plant resulted in 0.32 and 0.05 tunnel only. The release of 8, 12 and 16 larvae / plant did not have significant difference among each other and tunnel numbers formed were at par.

4.1.3.2 African tall:

The data on tunnel numbers (Table 4) in African tall during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly showed that tunnel numbers were relatively more in African tall compared to HQPM-1. It is evident from the Table 4 that release of larvae at 4, 8, 12 and 16 per plant resulted in 0.90, 1.13, 1.67 and 2.37 number of tunnels per plant respectively. It is also visible from the data that release of 28 and 32 larvae / plant (T_7 and T_8) transformed all infested plants in dead hearts and therefore, no tunnels were observed whereas 0.10 tunnel per plant was observed after the release of 24 larvae / plant (T_6). Number of tunnels formed in T_6, T_7 and T_8 were statistically at par.

Similar results were obtained during 2009 by recording varied number of tunnels, nil to 2.36. Maximum tunnels, 2.36 per plant, were recorded with release of 16 larvae / plant whereas minimum (0.00) tunnels were observed with release of 28 and 32 larvae / plant. The release of 4, 8 and 12 larvae / plant resulted in, 1.10, 1.23 and 1.79 tunnels per plant, respectively which were significantly at par but different from other treatments. The release of 20 and 24 larvae / plant gave 0.55 and 0.15 tunnels per plant respectively which were significantly different from each other.

Pooled analysis of two years data showed the similar trend wherein release of 16 larvae / plant resulted in maximum tunnel numbers (2.37 per plant) and differed from other treatments followed by 1.73, 1.18 and 1.00 tunnel plant after release of 12, 8 and 4 larvae / plant, respectively which were significantly differed from each other. No tunnels were found where 28 and 32 larvae per plant were released. The release of 20 and 24 larvae / plant gave 0.50 and 0.12 tunnels respectively which were statistically different to each other.

4.1.4 Effect of release rate of *C. partellus* on tunnel length in maize

The release of 4, 8, 12, 16, 20, 24, 28 and 32 neonate larvae of maize stem borer on the individual maize plants at susceptible stage, 12 to 16 days after germination resulted in the varied length of tunnel which were measured and presented in the Table 5 and depicted in Fig. 4a and 4b.

4.1.4.1 HQPM-1:

The data on tunnel length in HQPM-1 during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly showed that all treatments differ significantly to each other. It is apparent from the Table 5 that tunnel length varied from 2.36 to 9.29 cm during 2008 with release of varied number of larvae from 4 to 24 per plant, whereas, the release of 28 and 32 larvae / plant resulted in short and few tunnels (0.82 and 0.22 per plant) due to destruction of plants. The longest tunnel length, 9.29 cm, was observed with release of 24 larvae / plant followed by 7.02, 4.35, 4.26, 3.59 and 2.36 cm with release of 20, 16, 12, 8 and 4 larvae / plant, respectively. All treatments differ significantly to each other.

Similar trend was observed during 2009 wherein tunnel length varied from 2.06 to 8.43 cm. Longest tunnel length (8.43 cm) was observed after the release of 24 larvae / plant followed by 8.36, 5.13, 4.58, 3.49 and 2.06 cm with release of 20, 16, 12, 8 and 4 larvae / plant, respectively. Treatments of T_1 to T_5, were significantly different to each other whereas T_5 and T_6 were found statistically at par. The tunnel length in T_7 and T_8 were shortest (0.38 and 0.23 cm) respectively due to formation of dead hearts and destruction of plants and both treatments were found statistically at par.

Pooled analysis of the two years data showed the similar trend wherein release of 24 larvae / plant resulted in longest tunnel length (8.86cm) whereas release of 28 and 32 larvae / plant resulted it to 0.60 and 0.23 cm tunnel length only. It is also

apparent from the Table 5 that all the treatments differed significantly to each other. The data show gradual increase in tunnel length up to T_6 with increase in number of larvae released.

4.1.4.2 African tall:

The data on tunnel length (cm) in African tall during 2008 and 2009 after release of 4 to 32 neonate larvae of *C. partellus* per plant, after 12 to 16 days after germination are presented in Table 5. It is evident from the data that total length of tunnel caused by stem borer increased with increase in the number of larvae up to 24 / plant while no tunnel length was formed after release of 28 and 32 larvae / plant due to complete mortality of the plants. The tunnel length increased from 4.61 to 15.32 cm per plant with gradual increase in number of larvae from 4 to 16 per plant. The tunnel length was reduced to 3.04 and 0.41 cm after the release of 20 and 24 larvae / plant respectively and recorded nil after release of more larvae.

Similar results were obtained during 2009 by recording varied tunnel length from 0.00 to 15.19 cm. The tunnel length increased from 6.14 cm to 15.19 cm per plant with gradual increase in number of larvae from 4 to 16 per plant. The tunnel length was decreased to 0.70 and 0.13 cm after the release of 20 and 24 larvae / plant respectively and recorded nil after release of more larvae.

Pooled data analysis clearly show the similar trend of results. Almost zero tunnel length was recorded after release of 28 and 32 larvae / plant due to complete mortality of the plants. The release of 20 and 24 larvae / plant resulted in 1.87 and 0.27 cm tunnel length per plant, respectively. The tunnel lengths observed with 4, 8, 12 and 16 larvae / plant were 5.37, 6.62, 10.82 and 15.26 cm, respectively.

4.1.5 Effect of release rate of *C. partellus* on yield of maize

The data recorded on yield after the release of variable number of larvae of maize stem borer per plant are presented in Table 6 and depicted in Fig. 5a and 5b.

4.1.5.1 HQPM-1:

The data on grain yield (g / plant) in HQPM-1 during 2008 and 2009 after release of neonate larvae of *C. partellus* clearly showed that all treatments differ significantly to each other. It is evident from the Table 6 that during 2008, highest yield (131.28g / plant) was recorded in T_1 (4 larvae / plant) followed by 100.91, 82.10, 74.98, 64.28, 53.34, 15.73 and 7.58 g / plant in T_2, T_3, T_4, T_5, T_6, T_7 and T_8,

respectively. All treatments differed significantly to each other. The results showed gradual decrease of yield with increase in number of larvae released per plant.

Similar results were obtained during 2009 by recording varied yield. Maximum yield (127.4 g / plant) was recorded with release of 4 larvae / plant whereas lowest yield (7.10 g / plant) was observed with release of 32 larvae / plant. It is also visible from the data that 100.30 and 96.58 g / plant yield were recorded in T_2 and T_3 respectively which were statistically at par. The release of 16, 20, 24, 28 and 32 larvae per plant limited the yield to 81.44, 69.90, 54.39, 15.95 and 7.10 g / plant respectively. The gradual increase in the number of larvae released per plant decreased the yield sharply.

Pooled analysis of the two years data showed the similar trend wherein release of 32 larvae / plant resulted in higher reduction in yield, followed by 15.84, 53.87, 67.09, 78.21, 89.34, 100.60 and 129.34 per plant with release of 28, 24, 20, 16, 12, 8 and 4 larvae / plant, respectively. It is apparent from Table 6 that all the treatments differed significantly to each other and increased in the number of larvae released decreased the yield significantly.

4.1.5.2 African tall:

The data presented in Table 6 showed that release of 24 to 32 larvae / plant completely killed the plant of African tall and no yield was found. Maximum yield, 100.03 g / plant was recorded with the release of 4 larvae / plant followed by 77.80, 40.62, 12.99 and 5.34 g / plant with release of 8, 12, 16 and 20 larvae / plant, respectively.

Similar trend was also observed during 2009 wherein no yield was recorded with release of 24, 28 and 32 larvae / plant whereas yield of 98.74, 75.60, 43.50, 11.0 and 5.54 g / plant was recorded with release of 4, 8, 12, 16, and 20 larvae / plant respectively. The treatments T_1, T_2, T_3, T_4 and T_5 were significantly differed to each other, while T_6, T_7 and T_8 were found statistically at par.

Pooled analysis also showed the similar trend by giving maximum yield (99.38 g / plant) with release of minimum number of 4 larvae per plant followed by 76.70, 42.06, 11.99 and 5.44 g / plant in T_2, T_3, T_4 and T_5, respectively. Release of 24, 28 and 32 larvae / plant completely killed the plants and no yield was found.

4.1.3 Correlation between damage symptoms and yield

The release of neonate larvae of maize stem borer at 4 to 32 larvae / plant at 12 to 16 DAG in HQPM-1 and African tall resulted in different type of damage

symptoms and their intensity also varied in accordance with genetic resistance of plant. Therefore, the results obtained on LIR, plant height, tunnel number and tunnel length were correlated with yield and presented in Table 7 to 10.

4.1.3.1 Correlation between damage symptoms and yield in HQPM-1

The data recorded (Table 7) on LIR, plant height, tunnel number, tunnel length and yield were analyzed for their multiple and partial correlation. It is visible from the Table 7 that the correlation between yield and the combined effect of independent variables *viz.*, LIR, plant height, tunnel number and tunnel length on yield during 2008 was highly significant (R=0.993). The partial correlation between LIR and plant height and LIR with yield showed significant negative correlation r =-0.981 and -0.983, respectively which expressed that the increase in the LIR decreased the plant height and yield. The correlation between LIR and tunnel number (r =-0.346) as well as LIR and tunnel length (-0.106) were negative but non significant. The partial correlation between plant height and tunnel number and plant height and tunnel length were non significant but positive being 0.499 and 0.264 respectively whereas correlation between plant height and yield was highly significant but positive (r = 0.978). It showed that increase in the plant height also increase the yield. The correlation between tunnel number and tunnel length was significant positive with r = 0.955 while tunnel number and yield was only positive being r =0.435. The correlation between tunnel length and yield was found non significant but positive being r = 0.221. It is clear from the Table that the tunnel length was positively correlated with tunnel number.

The data presented in Table (8) revealed that the correlation between yield and the combined effect of independent variables viz. LIR, plant height, tunnel number and tunnel length on yield during 2009 was highly significant (R=0.995). The partial correlation between LIR and plant height and LIR with yield showed significant negative correlation r = -0.988 and - 0.982, respectively which means increase in LIR decreased the plant height and yield. The correlation between LIR and tunnel number (r = - 0.352) and LIR and tunnel length (- 0.145) were negative but non significant. The partial correlation between plant height and tunnel number and plant height and tunnel length were non significant but positive being 0.446 and 0.237 respectively whereas correlation between plant height and yield was highly significant and positive (r = 0.985). It showed that increase in plant height also increased the yield. The correlation between tunnel number and tunnel length was significant (r = 0.959)

positive while tunnel number and yield was only positive correlation being r = 0.477. The correlation between tunnel length and yield was found non significant and positive (r = 0.293). It is clear from the table that the tunnel length was positively correlated with tunnel number.

4.1.3.2 Correlation between damage symptoms and yield in African tall:-

Table (9) revealed that the correlation between yield and the combined effect of independent variables *viz.*, LIR, plant height, tunnel number and tunnel length on yield was highly significant (R=0.983 during 2008). The partial correlation between LIR and plant height and LIR with yield showed significant negative correlation, r = -0.960 and -0.945, respectively which indicates that increase in the LIR decreased the plant height and yield. The correlation between LIR and tunnel number as well as LIR and tunnel length were negative (r = - 0.584 and – 0.529, respectively) but non significant. The partial correlation between plant height and tunnel number and plant height and tunnel length were significantly positive (0.740 and 0.698 respectively) whereas correlation between plant height and yield was highly significant and positive (r = 0.839). It showed that increase in plant height also increased the yield. The correlation between tunnel number and tunnel length was highly significant and positive only (r = 0.996) while tunnel number and yield was positive (r = 0.346). The correlation between tunnel length and yield was found non significant but positive (r = 0.283). It is clear from the table that the tunnel length was positively correlated with tunnel number.

The data analyzed for 2009, table (10) revealed that the correlation between yield and the combined effect of independent variables *viz.*, LIR, plant height, tunnel number and tunnel length on yield was highly significant (R=0.999). The partial correlation between LIR and plant height and LIR and yield showed significant negative correlation (r = - 0.950 and – 0.989 respectively) which expressed that the increase in LIR decreased the plant height and yield. The correlation between LIR and tunnel number and LIR and tunnel length were negative (r = - 0.531 and -0.482 respectively) but non significant. The partial correlation between plant height and tunnel number was significantly positive being r = 0.740 whereas correlation between plant height and tunnel length as well as plant height and yield were highly significant and positive (0.985 and 0.907 respectively). It showed that increase in plant height also increased the yield. The correlation between tunnel number and tunnel length was highly significant and positive (r = 0.985) while tunnel number and yield was

only but positive (r = 0.408). The correlation between tunnel length and yield was found non significant positive being r = 0.364. It is clear from the table that the tunnel length was positively correlated with tunnel number.

4.2 Standardization of multiplication technique of *C. flavipes*

The investigations on requirement of specific host age and space for parasitizations and storage of *C. flavipes* cocoons were conducted during 2009 and results obtained are presented here under:

4.2.1 Preference of larval age for maximum offspring of *C. flavipes*

The female of *C. flavipes* prefers specific size and age larvae of *C. partellus* for egg laying. It is therefore planned to investigate the preferred size and age of *C. partellus* larvae for parasitization. The larvae of different aged i.e. 5, 8, 11, 14, 17 and 20 days old were offered to the females under confined cages and data recorded on per cent parasitization, number of cocoons per larva and sex ratio are presented in Table 11, depicted in Fig. 6 and Plate 4.

4.2.1.1 Parasitization:

The data recorded on per cent parasitization (Table 11) showed that preference of 17 and 20 days old larvae of *C. partellus* was highest with maximum parasitization (82.61 and 82.46 per cent respectively) followed by 72.82, 45.41 and 34.79 per cent in 14, 11 and 8 days old larvae, respectively. It was also evident from the Table 11 that no parasitization was observed in 5 days old larvae of *C. partellus*. The increase in the age of larvae increased the parasitization from 34.79 to 82.61 per cent. Most of the treatments differed significantly to each other while T_5 (17 days old larvae) and T_6 (20 days old larvae) were found statistically at par.

4.2.1.2 Cocoon formation:

The data recorded on number of cocoons (Table 11and Plate 5) showed that preference of 17 days old larvae of *C. partellus* was highest with maximum 43.09 number of cocoons formed followed by 42.70, 27.33, 16.19 and 12.50 cocoons per larva in 20, 14, 11 and 8 days old larvae, respectively. It was also evident from Table 11 that no cocoons were formed in 5 days old larvae of *C. partellus*. The increase in age of larvae increased the number of cocoons formed from 12.50 to 43.09 cocoons per larva. Most of the treatments differed significantly to each other while T_5 (17 days old larvae) and T_6 (20 days old larvae) were found statistically at par.

4.2.1.3 Sex ratio:

The data observed on sex ratio of adults emerged from different aged larvae showed that 11 and 14 days old larvae were highly preferred by giving significantly maximum female biased sex ratio of, 0.88, but were significantly at par with 8 days old larvae where sex ratio was 0.86. It is also apparent from the table that 17 and 20 days old larvae were at par by giving 0.82 and 0.83 female respectively. The data also showed that no adults of *C. flavipes* were emerged from 5 days old larvae of *C. partellus* and therefore no sex ratio was reported.

4.2.2 Effect of space on the efficiency of *C. flavipes*

The effect of space on parasitization, number of cocoons formed per larva and sex ratio of emerged adults at different host larval density was investigated by provision of different ovipositional chambers and data recorded are presented in Table 12 to 14 and depicted in Fig. 7 to 9.

4.2.2.1 Parasitization:

To investigate the effect of space and larval density on parasitization of *C. flavipes,* different ovipositional chambers *viz*., test tube (12 × 2.5cm^2), pearl pet jar of 500 (11 × 8cm^2), 1000 (16 × 10cm^2) and 2000 (23 × 12cm^2) g capacity were used and data thus observed are presented in Table12 and depicted in Fig. 7. It is visible from the data that the provision of single larva to one pair of adult of *C. flavipes* in test ovipositional chamber resulted in maximum parasitization, 89.56 per cent in test tube followed by 88.05, 76.53 and 66.79 per cent in pearl pet jar of 500, 1000 and 2000 g capacity, respectively. It is also apparent from the data that the parasitization recorded in test tube was higher to other test chambers but significantly at par with pearl pet jar of 500 g and different to the jars of 1000 and 2000 g.

The provision of two larvae in different ovipositional chambers resulted in significantly maximum parasitization, 82.98 per cent in test tube followed by 77.89, 70.97 and 64.04 per cent in pearl pet jars of 500, 1000 and 2000 g respectively. Similar results were observed with availability of three larvae per pair adult parasitoid wherein significantly maximum parasitization, 75.45 per cent, was recorded in test tube followed by 71.78, 63.56 and 53.02 per cent, in pearl pet jar of 500, 1000 and 2000 g respectively. The data obtained with 4 larvae per pair of adult parasitoid also showed resemblance with earlier results wherein test tube was found best for parasitization with 68.02 per cent followed by 66.09, 60.56 and 49.98 per cent. All

test ovipositional chambers were found statistically differed to each other. The data recorded with provision of 5 larvae to the single pair of parasitoid adults in different ovipositional chambers showed that the test tube found to be best with 54.55 per cent parasitization, but statistically it was at par with 57.44 per cent in pearl pet jar of 500 g. It is also clear that test tube was significantly superior to pearl pet jar of 1000 and 2000 g capacity wherein 56.27 and 42.24 per cent parasitization could record.

4.2.2.2 Cocoon formation:

To investigate the effect of space and larval density on cocoon formation of *C. flavipes*, different ovipositional chambers *viz.*, test tube, pearl pet jar of 500, 1000 and 2000 g were used and data thus obtained are presented in Table 13 and depicted in Fig. 8. It is visible from the data that the provision of single larva to the one pair of adults of *C. flavipes* in test ovipositional chambers resulted in minimum number (35.20) of cocoon formation, in pearl pet jar of 2000 g while maximum (37.53) was recorded in test tube followed by 37.13 and 36.28 cocoon formation in pearl pet jar of 500 and 1000 g respectively. It is also evident from the data that the number of cocoons formed in test tube was higher than other test chambers but significantly at par with pearl pet jar of 500 and 1000 g and different to the jar of 2000 g.

The provision of two larvae in different ovipositional chambers showed that significantly maximum (19.21) number of cocoons were formed in test tube followed by 18.58, 18.48 and 18.71 cocoons in pearl pet jar of 500, 1000 and 2000 g respectively. It is also apparent that all the treatments were statistically at par with each other. Similar results were observed with availability of three larvae per pair adult parasitoid wherein significantly maximum cocoons (12.53) were recorded in pearl pet jar of 500 g followed by 12.29, 12.45 and 11.81 cocoons in test tube, pearl pet jar of 1000 and 2000 g, respectively. All the treatments were statistically at par with each other. The data obtained with 4 larvae per pair of parasitoid adults also showed resemblance with earlier results wherein pearl pet jar of 1000 g was found best for cocoon formation with 9.81 number which was statistically at par with all treatments followed by 9.05, 8.91 and 8.78 in test tube, pearl pet jar of 500 and 2000 g, respectively. The data recorded with provision of 5 larvae to the pair of parasitoid adults in different ovipositional chambers showed that pearl pet jar of 500 g found best with, 7.61 number of cocoons but statistically at par with 7.03, 7.11 and 6.65 in test tube, pearl pet jar of 1000 and 2000 g respectively. It is also clear that all the treatments were statistically at par.

4.2.2.3 Sex ratio:

The effect of different sized ovipositional chambers on sex ratio of *C. flavipes* was investigated. The ovipositional chambers used were test tube, pearl pet jar of 500, 1000 and 2000 g and data thus obtained are presented in Table 14 and Plate 6. It is visible from the data that the provision of single larva to the one pair of adults of *C. flavipes* in test ovipositional chamber resulted in maximum sex ratio, 0.80, in test tube followed by 0.78, 0.72 and 0.53 sex ratio in pearl pet jar of 500, 1000 and 2000 g respectively. It is also apparent from the data that the sex ratio recorded in test tube was higher than other test chambers but significantly at par with pearl pet jar of 500 g and differed with the jar of 1000 and 2000 g. The provision of two larvae in different test ovipositional chambers resulted in significantly maximum sex ratio (0.82) in test tube and 0.80 in pearl pet jar of 500 g but was statistically at par with each other. The sex ratio of 0.74 and 0.70 observed in pearl pet jar of 1000 and 2000 g respectively was significantly differed to each other. Similar results were observed with availability of three larvae per pair adult parasitoid wherein maximum sex ratio (0.83) was recorded in test tube followed by 0.78, 0.75 and 0.65 in pearl pet jar of 500, 1000 and 2000 g, respectively. The data obtained with four larvae per pair adult parasitoid also showed resemblance with earlier results wherein test tube was found best for sex ratio with 0.82 followed by 0.80, 0.71 and 0.68 sex ratio in pearl pet jar of 500, 1000 and 2000 g respectively. Among all test ovipositional chambers, test tube and pearl pet jar of 500 g were found statistically at par with each other while pearl pet jar of 1000 and 2000 g were statistically at par but differed with T_1 (test tube) and T_2 (jar of 500 g). The data recorded with provision of 5 larvae to the single pair of parasitoid adults in different ovipositional chambers showed that test tube and pearl pet jar of 500 g found best with 0.80 sex ratio. It is also clear that test tube and pearl pet jar of 500 g were significantly superior to pearl pet jar of 1000 and 2000 g wherein respectively 0.69 and 0.62 sex ratio were recorded.

4.3 Effect of temperature during storage on the efficiency of *C. flavipes*

The cocoons of *C. flavipes* were stored at different temperatures for varied durations to know the effect of temperatures on the adult emergence, sex ratio and number of cocoons formed in successive generation. The data thus obtained are presented in Table 15 to 17 and depicted in Fig. 10 to 12.

4.3.1 Adult emergence:

The data recorded on adult emergence after storage at different temperatures *viz*., 5, 10, 15 and 20°C for varied durations *viz*., 10, 15, 20, 25 and 30 days are presented in Table 15. It is clear from the data that storage of cocoons for 10 days at different temperature did not affect the adult emergence. The minimum adult emergence (95.96 per cent) was observed at 10°C while maximum (97.58 per cent) was recorded at 20°C followed by 96.76 and 96.44 per cent at 15 and 5°C, respectively. It is also evident from the data that adult emergence at 20°C was significantly higher to 10°C but it was at par with 5 and 15°C. The data recorded for 15 days of storage at different test temperatures showed maximum adult emergence (98.46 per cent) at 20°C followed by 97.46, 96.64 and 95.22 per cent at 15, 10 and 5°C, respectively. It is also visible from the data that adult emergence at 20°C was significantly superior to 5 and 10°C but it was at par with 15°C. The cocoons stored for 20 days at different temperatures showed nil adult emergence at 20°C as emergence were earlier than test storage period. In the remaining test temperatures, maximum adult emergence (93.20 per cent) was observed at 15°C followed by 92.96 and 90.94 per cent at 10 and 5°C respectively. The data also showed that adult emergence at 10 and 15°C temperature was significantly at par while superior to 5°C. The observations recorded after 25 days of storage showed that at 15 and 20°C temperature, adults emerged prior to 25 days while emergence at 5 and 10°C was statistically at par. Similar results were obtained after prolonged storage for 30 days where 68.9 per cent adult emergence was recorded at 5°C. The storage of cocoons for longer duration in temperature ranges between 10 to 20°C, helped in the adult emergence earlier than required storage duration.

4.3.2 Sex ratio:

The data recorded on sex ratio of emerged adults after storage at different temperatures viz., 5, 10, 15 and 20°C for varied durations viz., 10, 15, 20, 25 and 30 days are presented in Table 16. It is clear from the data that storage of cocoons for 10 days at different temperatures affect the sex ratio. Minimum sex ratio (0.28) was observed at 5°C while maximum (0.85) was recorded at 20°C followed by 0.68 and 0.51 at 15 and 10°C respectively. It is also evident from the data that all the treatments were significantly differed to each other. The data recorded after 15 days of storage at different test temperature showed maximum sex ratio (0.82) at 20 °C followed by 0.71, 0.54 and 0.26 at 15, 10 and 5°C, respectively. It is also visible from the data that sex ratio at 20°C was significantly superior to 15, 10 and 5°C and all the treatments differed significantly to each other. The sex ratio after 20 days of storage at 15, 10 and

5°C was 0.76, 0.60 and 0.38, respectively while in 20 days of storage the sex ratio could not be observed due to prior emergence of adults. The data also showed that sex ratio in all treatments significantly differed to each other. The observations recorded after 25 days of storage of cocoons at 15 and 20°C could not inhibit the development and adults were emerged before the observations while at 5 and 10°C temperature sex ratio was 0.24 and 0.54 respectively and both were significantly differed to each other. Similar results were obtained after prolonged storage for 30 days where 0.39, sex ratio was recorded at 5°C while in storage temperature of 10 to 20°C, adult emergence was observed before the observation schedule and therefore, sex ratio could not be recorded.

4.3.3 Cocoon formation:

The data observed on number of cocoons formed from emerged adults are presented in Table 17. The data showed that storage of cocoons for 10 days at different temperatures affect the number of cocoons in successive generation. Minimum number of cocoons (20.20) were observed at 5°C while maximum (47.08) were recorded at 20°C followed by 30.93 and 28.84 at 15 and 10 °C respectively. It is also evident from the data that number of cocoons formed at 20 °C were significantly higher to 15, 10 and 5°C, while cocoons formed at 15°C were at par with 10 °C but significantly higher to 5°C temperature. The data recorded after 15 days of storage of cocoons at different test temperatures resulted in maximum cocoons (37.17) at 20°C temperature followed by 18.97, 17.61 and 17.45 at 10, 5 and 15°C, respectively. It is also visible from the data that cocoons formed at 20°C were significantly superior to all other treatments, while cocoons formed at 5, 10 and 15°C temperature were statistically at par with each other. It is also evident from the table that storage of cocoons for 20 days onwards at 5, 10 and 15°C temperature facilitated the formation of 10.53, 12.23 and 17.40 cocoons, respectively while at 20°C zero cocoon were formed due to nil emergence of adults in the previous generation. The data also showed that all the treatments were significantly differed to each other. It is visible from the data that prolonged storage for 25 days onwards in above 15°C temperature does not retard the development and therefore, all cocoons formed prior to observation schedule, while storage at 5 and 10°C helped in the formation of 8.45 and 8.33 cocoons respectively. Similar results were obtained after prolonged storage for 30 days where 3.39 cocoons were recorded at 5°C but storage at 30 days onwards does not inhibit the development, hence, no cocoon formation could been recorded in the scheduled date due to nil adult emergence in the previous generation.

5. DISCUSSION

5.1 Determination of correlation between damage symptoms caused by *C. partellus* and yield in maize

The artificial infestation of maize plants at 12 to 16 DAG, with different larval density / plant exhibited varying degree of infestation in the plants. The infestation caused by larvae was graded after one month of release as per the proposed Leaf Injury Rating (Chatterji *et al.* 1969). These infestations differ from spiral holes and slits in few leaves to all leaves, dead hearts and holes in the stems and the grading of these symptoms is represented as Leaf Injury Rating (LIR) scale (1-9). The plant which showed low LIR, 1-3 is considered as resistant, > 3 to 6 as moderately resistant and > 6 to 9 as susceptible against *C. partellus*. The rating differ to germplasmwise as resistant plant exhibited less rating compared to susceptible one. The screened germplasm either was rejected or accepted on the basis of LIR for further breeding programme whereas plant tried to reequip the losses during further growth and development.

In present investigation results of correlation between damage symptoms caused by *C. partellus* in HQPM-1 and African tall and maize yield are discussed herewith as under.

5.1.1 Effect of release rate of *C. partellus* on damage potential (LIR) in maize

The results obtained on LIR in HQPM-1 and African tall during 2008 and 2009 are presented in Table 2 and depicted in Fig 1a and 1b. It is evident from the Table 2 that LIR of HQPM-1 varied from 1.64 to 8.92 in 2008 and 1.82 to 8.89 in 2009 whereas in African tall it ranged from 4.19 to 9.00 in 2008 and 4.28 to 9.00 in 2009 after release of 4 to 32 larvae / plant at 12 to 16 DAG. It is also apparent from the table that increase in release rate of neonate larvae of *C. partellus* from 4 to 32 larvae per plant significantly increased the damage symptoms and LIR. The release of 4 and 8 larvae / plant in HQPM-1 resulted in 1.64 and 2.80 LIR in 2008 and 1.82 and 2.78 in 2009, respectively, while release of 8, 12 and 16 larvae per plant resulted in 3.81, 4.89 and 5.81 LIR in 2008 and 3.94, 4.86 and 5.90 LIR in 2009 respectively. It is also visible from the table that recorded LIR for 4 to 20 larvae / plant was in between 3 to 6 which reflect the moderate resistant nature of the plants. The increase

in the number of larvae for release i.e.> 20 larvae / plant created heavy pest damage and transformed plant to susceptible one with LIR i.e. > 6.0 during both years of investigation. The pooled analysis resemble with 2008 and 2009 results.

The data recorded on LIR of African tall clearly express the susceptible nature of cultivar wherein release of 4 larvae / plant resulted in 4.19 and 4.28 LIR during 2008 and 2009 followed by 5.36 and 5.19 after release of 8 larvae / plant during 2008 and 2009 respectively. In contrary to HQPM-1 it was evident from the data that African tall tolerate little infestation of 4 and 8 larvae of maize stem borer and henceforth expressed moderate resistant nature of cultivar at this release rate. Further, release of 12 to 32 larvae / plant caused heavy infestation and graded between 6 to 9 LIR which expressed the susceptible nature of cultivar. It is also clear from the data that release of 28 and 32 larvae / plant resulted in total dead hearts transformed plants with 9.00 LIR while release of 20 and 24 larvae / plant were also very similar to dead hearts formed plants and index varied from 7.59 to 8.37 during 2008 and 2009. The pooled analysis of two years data resembles with earlier results. It is thus clear that damage symptoms formed in the plants after the release of different number of larvae express the resistance of plants. The comparison of LIR recorded in HQPM-1 and African tall showed the similar views wherein HQPM-1 expressed moderate resistance up to 16 larvae / plant in contrary to 8 larvae / plant in African tall. Further release of more than 24 larvae in HQPM-1 only transformed the plant to more susceptible rank while in African tall it was found after the release of 12 larvae / plant. The present findings are in agreement with the work of Panwar *et al.* (2001) who reported that LIR of exotic germplasm to *C. partellus* under artificial infestation ranged from 4.3 to 9.00. Similarly Reddy (2003) observed varied LIR, 2.7 to 5.6 in the screening of maize germplasms of full season, medium, early and extra early maturity group. Chavan *et al.* (2007) evaluated seventy seven maize germplasm lines against maize stem borer under artificial infestation and reported LIR from 2.4 to 6.4. Jindal and Hari (2008) screened five germplasms namely CML 67, CM 500, DMH 1, JH 3459 and Basi local against maize stem borer and found CM 500 with minimum LIR, 3.99 ± 0.12 while Basi local was considered with maximum LIR, 6.39 ± 0.46.

5.1.2 Effect of release rate of *C. partellus* on plant height in maize

The results obtained on plant height in HQPM-1 and African tall during 2008 and 2009 are presented in Table 3 and depicted in Fig. 2a and 2b. The data revealed

that plant height in HQPM-1 varied from 33.79 to 155.85 cm in 2008 and 31.52 to 152.95 cm in 2009 after the release of 4 to 32 larvae / plant whereas in African tall it was from 17.49 to 261.94 cm in 2008 and 19.36 to 263.75 cm in 2009. It is also apparent from the table that increase in the release rate of neonate larvae of *C. partellus* from 4 to 32 larvae / plant significantly decreased the plant height. The release of 4 and 8 neonate larvae / plant in HQPM-1 resulted in tallest plant, 155.85 and 149.34 cm during 2008 and 152.95 and 145.70 cm in 2009 respectively. The increase in number of larvae released at 12, 16 and 20 larvae / plant, resulted in decreased plant height, 132.94, 116.57 and 95.00 cm during 2008 and 134.87, 118.36 and 92.97 cm during 2009 respectively. The artificial infestation of plants with 20 and more larvae / plant created heavy reduction in plant height during both the years of investigation. The pooled analysis also resemble with the results of 2008 and 2009.

The data recorded on plant height of African tall after release of neonate larvae in different numbers clearly express the susceptible nature of cultivar wherein release of 4 and 8 larvae / plant resulted in tallest plant height, 261.94 and 259.99 cm in 2008 and 263.78 and 255.81 cm in 2009 respectively. In contrary to HQPM-1 it is visible from the data that African tall show reduction in plant height after release of 12 to 32 larvae / plant. Release of 24, 28 and 32 neonate larvae / plant resulted in complete dead heart formation which expressed the susceptible nature of cultivar. The pooled analysis of two years data also expressed the similar results. It is evident from the data that HQPM-1 tolerated infestation of 24 larvae / plant which expressed the resistant character of plant whereas African tall could tolerate only 8 larvae / plant and huge reduction in plant height was noticed.

The findings of present investigation are in close conformity with the findings of many scientists. Songa *et al.* (2001) reported that infestation of maize plants with maize stem borer reduced plant height and yield significantly. Similarly, Awan and Khaliq (2003) recorded difference in the height of healthy and damaged plants in different cultivars due to maize stem borer being the maximum difference of 33 cm and minimum difference of 0.5 cm. Dass *et al.*(2006) observed that maize plant height of susceptible cultivar was adversely affected by *C. partellus* under severe infestation conditions while few inbreeds showed better resistance. Belay and Foster (2010) reported positive correlation between yields with plant height after the infestation of maize stem borer.

5.1.3 Effect of release rate of *C. partellus* on tunnels in maize

The results obtained on tunnel number in HQPM-1 and African tall after release of 4 to 32 neonate larvae / plant during 2008 and 2009 are presented in Table 4 and depicted in Fig 3a and 3b. The tunnel number / plant were inversely proportional to the resistance potential of cultivar. Maximum number of tunnels shows the susceptible nature of germplasm while minimum tunnel number shows the resistant nature. The tunnel number in HQPM-1 varied from 0.06 to 1.40 / plant in 2008 and 0.03 to 1.33 / plant in 2009 while in African tall, it ranged from 0.00 to 2.37 in 2008 and 0.00 to 2.36 in 2009. It is also apparent from the Table 4 that increase in release number of neonate larvae of *C. partellus* from 4 to 32 larvae / plant significantly increased the tunnel number except in those plants where dead hearts were formed. The release of 4 and 8 larvae / plant in HQPM-1 resulted in formation of 0.63 and 0.83 tunnels during 2008 and 0.59 and 0.85 tunnels during 2009 respectively. Maximum tunnels, 1.40 / plant, in HQPM-1 were observed after the release of 24 larvae / plant during 2008 followed by 1.01, 0.89, 0.90, 0.83 and 0.63 / plant with release of 20, 16, 12, 8 and 4 / plant respectively. Similar trend was observed in 2009 wherein release of 24 larvae / plant of HQPM-1 resulted in maximum number of tunnels 1.33 / plant, followed by 1.25, 0.94, 1.01, 0.85 and 0.59 / plant with release of 20, 16, 12, 8 and 4 larvae / plant respectively. This shows that number of tunnels are directly proportional to release rate of maize stem borer. The tunnel numbers were drastically reduced with 28 and 32 larvae / plant in 2008 and 2009 as most of the plants transformed to dead hearts. Similar results were observed in pooled analysis of two years data.

The data recorded on tunnel numbers in African tall during 2008 and 2009 showed that increase in release rate of maize stem borer larvae from 4 to 16 / plant increased the tunnel numbers during both the years of investigation. Maximum tunnels of 2.37 and 2.36, were recorded after the release of 16 larvae / plant during 2008 and 2009 respectively while minimum, 0.90 and 1.10, were observed with 4 larvae / plant during 2008 and 2009 respectively. It is also visible from the data that tunnel numbers were decreased, 0.45 and 0.10 / plant in 2008 and 0.55 and 0.15 / plant during 2009 respectively when 20 and 24 larvae / plant were released. No tunnels were found with 28 and 32 larvae / plant due to complete formation of dead hearts. The comparison of two years data of HQPM-1and African tall shows that maximum tunnels / plant i.e. 1.40 and 1.33 / plant in HQPM-1 were recorded during

2008 and 2009 with 24 larvae while in African tall, the release of 24 larvae / plant resulted in 0.10 and 0.15 tunnel / plant due to complete transformation of plants into dead hearts. It is also visible from the table that release of same number of larvae in two different germplasms HQPM-1 and African tall behaved differently. African tall shows susceptibility to maize stem borer after release of 20 larvae / plant with decrease in tunnels 0.45 / plant and conversion of plants in to dead hearts while HQPM-1 shows susceptibility at 28 and 32 larvae / plant with 0.31 and 0.06 tunnel per plant during 2008 and 0.33 and 0.03 during 2009 respectively. The pooled analysis of two years data also showed the similar trend.

The present investigation corroborates with the work of Kumar 1997a who reported that stalk tunneling by *C. partellus* was less in resistant germplasms compared to susceptible one. Similarly Belay and foster (2010) reported positive correlation between per cent cob damage and tunnel length.

5.1.4 Effect of release rate of *C. partellus* on tunnel length (cm) in maize

The data obtained on tunnel length (cm) in HQPM-1 and African tall after release of neonate larvae of maize stem borer from 4 to 32 / plant, during 2008 and 2009 are presented in Table 5 and depicted in Fig. 4a and 4b. The tunnel length is the representation of tolerance level of plant. The longest tunnel length has been considered as representation of susceptible nature of plants while shortest or nil tunnel length is expressed as resistant nature of plants. The data revealed that tunnel length in HQPM-1 varied from 0.22 to 9.29 cm during 2008 and 0.23 to 8.43 cm during 2009 whereas in African tall it ranged from 0.00 to 15.32 cm in 2008 and 0.00 to 15.19 cm in 2009. It is also apparent from the data that increase in number of larvae from 4 to 32 / plant significantly increased the tunnel length except those conditions where dead heart formation took place. The release of 4 and 8 larvae / plant in HQPM-1 resulted in 2.36 and 3.59 cm tunnel length during 2008 and 2.06 and 3.49 cm during 2009 respectively.

It is apparent from the data that increase in release rate of 24 larvae / plant, resulted in longest tunnel length, 9.29 cm in 2008 followed by 7.02, 4.35, 4.26, 3.59 and 2.36 cm with 20, 16, 12, 8 and 4 larvae / plant, respectively. Similar results were obtained in 2009 wherein longest tunnel length (8.43 cm) was recorded after the release of 24 larvae / plant followed by 8.36, 5.13, 4.58, 3.49 and 2.06 cm after the release of 20, 12, 16, 8 and 4 larvae / plant, respectively. It shows the positive

relationship of tunnel length with release rate. Release of more number of larvae, 28 and 32 / plant, completely destroyed the plants with dead heart symptoms and no tunnel length was recorded. The pooled analysis also resemble with the results of 2008 and 2009.

The data recorded on tunnel length of African tall clearly express the susceptible nature of cultivar wherein release of 4 larvae / plant resulted in 4.61 and 6.14 cm length in 2008 and 2009, followed by 6.94 and 6.30 cm tunnel length after release of 8 larvae / plant in 2008 and 2009 respectively. It is visible from the Table 5 that longest tunnel length (15.32 cm) was recorded after the release of 16 larvae / plant followed by 9.88 cm with 12 larvae / plant in 2008. The increase in larvae from 20 onwards / plant decreased tunnel length drastically due to complete transformation of dead hearts. The release of 20 and 24 larvae / plant during 2008 resulted in 3.04 and 0.41 cm tunnel length, respectively while no tunnel length was recorded at 28 and 32 larvae / plant. Similar results were obtained during 2009 wherein longest tunnel length (15.19 cm) was recorded with 16 larvae / plant followed by 10.69, 6.30 and 6.14 cm with 12, 8 and 4 larvae / plant, respectively. The release of 20 and 24 larvae / plant resulted in 0.70 and 0.13 cm tunnel length respectively while no tunnel was observed after release of 28 and 32 larvae / plant. The comparison of results of HQPM-1 and African tall clearly express the resistant potential of cultivar where longest tunnel length of 9.29 cm and 8.43 cm was recorded in HQPM-1 with 20 larvae / plant during 2008 and 2009, respectively while in African tall, longest tunnel length of 15.32 and 15.19 cm was recorded with 16 larvae / plant during 2008 and 2009, respectively. The shortest tunnel length, 4.61 and 6.14 cm, in African tall was recorded during 2008 and 2009 respectively with release of 4 larvae / plant while in HQPM-1 almost similar tunnel length (4.35 cm and 4.58 cm) was recorded with release of 16 larvae / plant. It clearly expressed the resistance potential of HQPM-1 which tolerates the infestation of 16 larvae / plant. It is also visible that release of more than 24 larvae / plant in HQPM-1 converted the plants to more susceptible while in African tall it was found after the release of 12 larvae / plant.

The findings of present investigation are supported by the findings of many workers. Barrow (1987) and Ajala (1994) observed that stem tunneling was the most important damage parameter causing yield loss in maize. Kumar and Asino (1994) reported that regression of maize grain yield on stem tunneling had negative relationship across maize genotypes. Kumar (1997a) reported highly significant

correlationship between number of holes and stem tunneling caused by *C. partellus*. Present investigations is also supported by Songa *et al.* (2001) who reported that *C. partellus* damage greatly reduced maize yield, with tunnel length greater than 20 cm caused a 40 per cent reduction in potential yield. Regression analysis indicated that one cm of stem borer tunnel reduced yield by 3 g / plant. Jindal and Hari (2008) reported that CM 500 had shortest tunnel length (3.97 ± 0.16 cm) while Basi local had longest tunnel length (7.27 ± 0.67 cm).

5.1.5 Effect of release rate of *C. partellus* on yield in maize

The maize harbors single to many larvae as an internal borer during growing season which reduce the grain yield drastically. Yield reduction vary according to the resistance potential of the data recorded on maize plant yield after artificial infestation with 4 to 32 larvae / plant in HQPM-1 and African tall during 2008 and 2009 are presented in Table 6 and depicted in Fig 5a and 5b and discussed as under. It is apparent from the table that increase in release of larvae from 4 to 32 larvae / plant significantly reduced the yield. The data revealed that yield in HQPM-1 varied from 7.58 to 131.28 g / plant in 2008 and 7.10 to 127.41 g / plant in 2009 while in African tall nil to 100.03 g / plant in 2008 and nil to 98.74 g / plant in 2009. It is also visible that release of minimum number 4 larvae / plant, resulted in maximum yield, 131.28 g / plant in HQPM-1 during 2008 followed by 100.91, 82.10, 74.98, 64.28, 53.34, 15.73 and 7.58 g with 8, 12, 16, 20, 24, 28 and 32 larvae / plant respectively. Similarly in 2009 highest yield, 127.41 g was recorded after the release of 4 larvae / plant followed by 100.30, 96.58, 81.44, 69.50, 54.39, 15.95 and 7.10 g after release of 8, 12, 16, 20, 24, 28 and 32 larvae / plant, respectively. Release of higher number of larvae i.e. 28 and 32 / plant gave almost negligible yield. It shows negative relationship of plant yield with release rate. The pooled data analysis also resemble with the results of 2008 and 2009.

The data recorded on yield of African tall clearly express the susceptible nature of cultivar wherein release of 4 larvae / plant resulted in maximum yield, 100.03 g / plant followed by 77.80, 40.62, 12.99 and 5.34 g / plant after release of 8, 12, 16 and 20 larvae / plant. Similar results were obtained in 2009 wherein maximum plant yield, 98.74 g / plant was recorded with release of 4 larvae / plant followed by 75.60, 43.50, 11.00 and 5.54 g / plant after the release of 8, 12, 16 and 20 larvae /

plant. It is also visible from the both years data that no yield was obtained after the release of 24, 28 and 32 larvae / plant.

The comparison of yield data of two years of HQPM-1 and African tall clearly shows the difference in the resistance potential to maize stem borer. The release of 24 to 32 larvae of maize stem borer in African tall destroyed the plant completely and no yield was recorded while in HQPM-1, the yield was recorded as 53.34, 15.73 and 7.58 g / plant in 2008 and 54.39, 15.95 and 7.10 g / plant in 2009 respectively. It is also visible from Table 6 that the release of 12, 16 and 20 larvae / plant in African tall reduced the yield drastically and recorded 40.62, 12.99 and 5.34 g / plant yield in 2008 and 43.50, 11.00 and 5.54 g / plant in 2009, respectively, while in HQPM-1 it was 82.10, 74.98 and 64.28 g / plant in 2008 and 96.58, 81.44 and 69.90 g / plant in 2009 respectively. The result shows heavy reduction of yield in African tall as compared to HQPM-1 with increase in released larvae / plant.

The present investigation is supported by Kumar and Asino (1994) who reported that grain yield of maize was influenced negatively by the damage caused by *C. partellus*. Kumar and Mihm (1996) also supported the present investigation with the view that resistant hybrids suffered little leaf and stalk damage and thus lost little grain yield in comparison to susceptible hybrids. Songa *et al.* (2001) observed that the stem borer damage, plant height and stem diameter were key factors affecting maize grain yield. Belay and Foster (2010) reported positive correlation between plant yield and plant height.

5.1.6 Correlation between damage symptoms and yield

The data recorded (Table 7) on LIR, plant height, tunnel number, tunnel length and yield were analyzed for their multiple and partial correlation. Data revealed that the correlation between yield and the combined effect of independent variables *viz*., LIR, plant height, tunnel number and tunnel length on yield was highly significant during 2008 and 2009.

5.1.6.1 Correlation between LIR with plant height, tunnel number, tunnel length and yield:

Correlation between LIR and plant height of HQPM-1 and African tall showed significant negative correlation being r = -0.981 and -0.988 in HQPM-1 and r = -0.960 and -0.950 in African tall during 2008 and 2009, respectively. This indicates that increases in the LIR responsible for the reduction of plant height.

It is visible from the Table 7 and 8 that the correlation between LIR and tunnel number was negative but non significant being r = -0.346 and -0.352 in HQPM-1 and r = -0.584 and -0.531 in African tall during 2008 and 2009, respectively. This clearly reflects that increase in number of larvae released in maize germplasm decreased the tunnel numbers.

The correlation between LIR and tunnel length showed negative but non significant in HQPM-1 (r = -0.106 and -0.145) and African tall (r = -0.529 and -0.482) during 2008 and 2009 respectively. This also state that tunnel length decreased if numbers of released larvae increased.

The correlation between LIR and yield in test corn showed highly significant negative correlation in HQPM-1 (r = -0.983 and -0.982) and African tall (r =-0.945 and -0.989) during both the years which expressed that increase in the LIR decreased the yield.

5.1.6.2 Correlation between plant height and tunnel numbers, tunnel length and yield:

The data recorded on plant height and tunnel number in HQPM-1 and African tall showed positive correlation but non significant in HQPM-1 (r = 0.499 and 0.446 in 2008 and 2009 respectively) while significant in African tall (r = 0.740 and 0.740 in 2008 and 2009 respectively).

The observation recorded on plant height and tunnel length showed positive correlation but non significant in HQPM-1 being r = 0.264 and 0.237 during 2008 and 2009 respectively while significant in African tall being r = 0.698 and 0.985 during 2008 and 2009 respectively. This express that the plant height in HQPM-1 was not affected much by tunnel length while in African tall, plant height drastically reduced with the increase in tunnel length.

The data obtained on plant height and yield of HQPM-1 and African tall showed highly significant positive correlation wherein, r = 0.978 and 0.985 were recorded in HQPM-1and r =0.839 and 0.907 in African tall during 2008 and 2009 respectively. It express that the plant height was directly related to yield.

5.1.6.3 Correlation between tunnel number with tunnel length and yield:

The data recorded on tunnel number and tunnel length were analyzed for their correlation which showed highly significant positive correlation in HQPM-1 with (r = 0.955 and 0.959 during 2008 and 2009, respectively) and (0.996 and 0.985 in African tall during 2008 and 2009 respectively). Tunnel numbers were also

represented by exit holes in the stem as more number of holes represent increase length of tunnel.

The correlation between tunnel number and yield was found non significant but positive in HQPM-1 being r = 0.435 and 0.477 during 2008 and 2009 respectively while in African tall it was 0.346 and 0.408 during 2008 and 2009, respectively.

5.1.6.4 Correlation between tunnel length and yield:

The correlation between tunnel length and yield was found non significant but positive in HQPM-1 being r = 0.221 and r = 0.293 during 2008 and 2009 respectively and in African tall it was 0.283 and 0.364 during 2008 and 2009, respectively.

A number of factors have earlier been reported to be associated with losses in yield caused by stem borer in maize such as leaf injury, plant height, tunnel number and tunnel length. The present findings are in agreement with the work of Kumar and Asino (1994) who reported that grain yield of various maize genotypes was influenced negatively with the damage caused by *C. partellus*. Similarly, Kumar (1997a) observed highly significant correlation between number of holes and stem tunneling. Songa *et al.* (2001) reported a highly positive correlation between plant height and grain yield of maize genotypes. Wale *et al.* (2006) recorded positive correlation between plant height and yield. Sharma *et al.* (2007) also supported present findings with their results. They observed that leaf feeding scores was positively associated with dead hearts and stem tunneling as the primary cause of yield loss. Ajala *et al.* (2010) also observed that plant height positively but non significantly correlated with stem tunneling and plant height and yield were positively correlated.

5.2 Standardization of multiplication technique of *C. flavipes*

5.2.1 Preference of larval age for maximum offspring of *C. flavipes*

Many parasitoids develop successfully in different stages of the same host but the costs of parasitism may vary between the stages. The stage of host attacked has generally been determined when there is no choice, giving a misleading impression of host selection or preference. The investigation on preference of different sized larvae *viz*., 5, 8, 11, 14, 17 and 20 days old larvae of *C. partellus* to *C. flavipes* was carried out and observations were recorded on per cent parasitization, number of cocoons and sex ratio of *C. flavipes* (Table11 and Fig. 6) are discussed herewith as under. Results

of the present study indicated that host stage is an important factor affecting parasitism, cocoon formation and development parameters of *C. flavipes.*

5.2.1.1 Parasitization:

It is apparent from the Table 11 that *C. flavipes* is able to parasitize to different aged larvae of *C. partellus* from 8 to 20 days while 5 days old larvae were not selected for parasitization. The parasitization on 17 and 20 days old larvae was highest with the maximum parasitization, 82.61 and 82.46 per cent respectively. It is very clear from the data that increase in the age of *C. partellus* provided more parasitization and thus leads to more offspring production. The persent investigation got support from by many workers. Sait *et al.* (1997) reported that solitary endoparasitoid wasp, *Venturia concescens* was able to parasitize all larval stages of the Indian meal moth, *Plodia interpunctella* Hubner except first instar. They found that second instars experienced significantly reduced parasitism in both refuge treatments, compared with third to fifth instars. Parasitoid emergence was always significantly less when all host stages had a refuge, the reduction was marginally significant when second instars were attacked. When a choice of second and fifth instars larvae were given wasps consistently parasitized more fifth instars, both with and without a refuge. Moreover, few or second instar larvae were parasitized in the presence of fifth instars than when presented alone to the wasps. Shi *et al.* (2002) observed that *C. plutella* could parasitize larvae of all four instars of *Plutella xylostella* (L.), but preferred 2^{nd} and 3^{rd} instars. In a choice test, the relative parasitism indices for 2^{nd}, 3^{rd}, and 4^{th} instars were 0.37, 0.39 and 0.24, respectively. Parasitism decreased sharply with increasing host age in the 4^{th} instar and approached zero in host larvae that had gone beyond 37 per cent of 4^{th} stadium. The development time and the final adult size of the parasitoid was varied with the host instar at initial parasitization. Parasitoids with initial parasitism in 4^{th} instar hosts had the shortest development time, followed by 3^{rd} and 2^{nd} instar. Parasitoids starting parasitism in 2^{nd} instar hosts were smaller in body size than those starting in the 3^{rd} or 4^{th} instar. However, resultant females starting parasitism in 3^{rd} instar hosts had the highest fecundity. Similarly Shekharappa and Kulkarni (2003) observed that third instar larvae of *C. partellus* were most suitable for parasitization by *C. flavipes*.

5.2.1.2 Cocoon formation:

The provision of different aged larvae of *C. partellus* to the females of *C. flavipes* for parasitization in the laboratory showed a significant positive

relationship between ages of host larvae and number of cocoons obtained. It means the number of offspring were more in heavier larvae. The present study revealed that preference of 17 and 20 days old larvae of *C. partellus* by *C. flavipes* was highest with significant maximum number of cocoon formed, 43.09 and 42.70 respectively while no cocoon was formed in 5 days old larvae of *C. partellus*. It is also apparent from the Table 11 that increase in size of larvae from 5 to 20 days increased the cocoon formation with significant difference among different tested size. It would be due to increase in the weight of larvae in context to increase in the days. Various workers have reported the similar views. The present investigation is in close agreement with Campos Farinha and Chaud Netto (2000) who observed that number of offspring of *C. flavipes* was greater when heavier third to fifth instar larvae of *D. saccharalis* were exposed. Similarly, Jalali and Singh (2002) also found the similar results and reported that 2nd to 6th instar of *C. partellus* provided significantly more parasitism, fecundity and shortest developmental period of *C. flavipes*. Jiang *et al*. (2004) observed that number of *C. flavipes* cocoons emerged per larva were significantly higher in 4th instar host larvae than 3rd instar larvae. They also reported that parasitized fourth instar contained more *C. flavipes* immature and produced more cocoons than third instar, suggesting that either the adult female adjust the number of eggs to be laid to the size of the host, or immature survival of the parasitoid is determined by the host size. In both cases, there is clear indication that *C. flavipes* regulates the host size for successful completion of its development.

5.2.1.3 Sex ratio:

The suitability of different aged larvae of *C. partellus* to *C. flavipes* showed that maximum females (0.86 to 0.88, in ratio) to male was emerged when 8 to 14 days old larvae were used but there was no significant difference among 8, 11 and 14 days age of *C. partellus*. It is also visible that provision of 17 and 20 days old larvae does not differ statistically to each other and gave 0.82 and 0.83 female but was significantly at par to the sex ratio observed in 8 to 14 days old larvae. No adult emergence was observed in 5 days old larvae.

The effect of different size and age of host larvae on the sex ratio of emerged adult parasitoid have been reported by several researchers. They indicated that host age might be a primary factor in determining effectiveness of a parasitoid. In an investigation on reproduction biology of *C. flavipes*, Campos Farinha and Chaud Netto (2000) reported exposure of third to fifth instar *D. saccharalis* larvae

individually to *C. flavipes* influence sex ratio which was biased towards females in all three instars, mainly when they received one, two and four egg layings while Jalali and Singh (2002) reported positive relationship between age of larvae of *C. partellus* and per cent female progeny of *C. flavipes.* In contrary, Jiang *et al.* (2004) reported that there was no effect of host stage, on progeny sex ratio of *C. flavipes* but might be a primary factor in determining effectiveness of a parasitoid.

5.2.2 Effect of space on the efficiency of *C. flavipes*

The interaction between host and parasitoid is essential for parasitization and the closest association increases the chances of parasitization. Ovipositional chambers of different size are being used for exposure of host to parasitoid. In the present investigation maize stem borer larvae were exposed to *C. flavipes* adult female in 4 type of ovipositional cages and data obtained on parasitization, number of cocoons formed and sex ratio (Table 12 to 14 and Fig.7 to 9) are discussed as under.

5.2.2.1 Parasitization:

The provision of 17 days old single larva to one pair of adults of *C. flavipes* in different ovipositional chambers showed that maximum parasitization, (89.56 per cent) was recovered, in test tube followed by 88.05, 76.53 and 66.79 per cent in pearl pet jar of 500, 1000 and 2000 g respectively. Data revealed that parasitization of maize stem borer larvae by *C. flavipes* decreased with increase in size of ovipositional chamber. Almost similar results were observed with two larvae of maize stem borer to *C. flavipes* in different ovipositional chamber, resulted in significantly maximum parasitization (82.98 per cent) in test tube and minimum parasitization (64.04 per cent) in pearl pet jar of 2000 g. Similar results were obtained after the provision of 3, 4 and 5 larvae to single pair of adults of *C. flavipes* in each ovipositional chamber. The data obtained on parasitization clearly shows the importance of close association between host and parasitoid where more parasitization was recorded in test tube compared to other ovipositional chambers.

5.2.2.2 Cocoon formation:

The data on the effect of space of different ovipositional chambers *viz.*, test tube, pearl pet jar of 500, 1000 and 2000 g capacity and larval density on cocoon formation of *C. flavipes* showed that maximum cocoons 37.53 were recorded in test tube but statistically at par with pearl pet jar of 500 and 1000 g while minimum, 35.20, in pearl pet jar of 2000 g. The increase in larval density from 2 to 5 larvae to

single pair of adult parasitoid in different ovipositional chambers showed the distribution of egg laid which resulted in decreased number of cocoons formed per larva. The data also showed non significant difference of test chambers on number of cocoons formed.

5.2.2.3 Sex ratio:

Sex ratio of parasitoid is affected by forced proximity of female parasitoids to their hosts. It is visible from the data that the provision of larvae to the one pair of adult of *C. flavipes* in test ovipositional chamber resulted in maximum sex ratio, 0.80, in test tube followed by 0.78, 0.72 and 0.53 sex ratio in pearl pet jar of 500, 1000 and 2000 g respectively. It is also apparent from the data that the sex ratio recorded in test tube was statistically superior to pearl pet jar of 1000 and 2000 g but was at par with pearl pet jar of 500 g. The provision of increased number of larvae from 2 to 5 to adult parasitoid showed that test tube and pearl pet jar of 500 g found suitable for sex ratio and were at par. On contrary increase in pearl pet jar, 1000 and 2000 g, reduced the sex ratio. The sex ratio in pearl pet jar of 2000 g was not female biased, hence, categorized least suitable.

The results of present investigation are supported by the research of various workers. Srikanth *et al.* (2000) reported that parasitization rates of *C. flavipes* to the borers of sugarcane and sorghum was negatively correlated with the number of larvae per female parasitoid. Tillman (2001) studied biological factors hypothesized to affect parasitization by *Cotesia marginiventris* on *Spodoptera exigua* as well as its sex ratio. He found that highest parasitization occurred when adult female parasitoids were closely associated with host and were one day old, a host: female parasitoid ratio of 10:1 and 30:1 was maintained, second instar *S. exigua* were used as host and adult female parasitoids were exposed to host for 24 hours. Percentage of female progeny was higher when females were closely associated with second instars.

5.3 Effect of temperature during storage on the efficiency of *C. flavipes*

Parasitoid's efficiency in controlling insect pests depends not only on their ability to parasitize their hosts but also on how much they are adapted to climatic conditions especially temperature of the area where they are planned to be released.

The storage of cocoons of *C. flavipes* at different temperature regimes (5, 10, 15 and 20°C) was investigated after recording the data on adult emergence, sex ratio

and number of cocoons formed in F_1 generation. The data thus recorded and presented in Table 15 to 17 and Fig.10 to 12 are discussed as under.

5.3.1 Adult emergence

Adult emergence from cold stored cocoons of *C. flavipes* varied with storage time and temperature. It is clear from the data that storage of cocoons for 10 days at different temperatures do not affect the adult emergence significantly and all the treatments were at par. Similarly storage of cocoons for 15 days at different temperatures also resulted in good adult emergence ranged from 95.22 to 98.46 per cent where adult emergence at 5°C temperature was statistically at par to 10 and 15°C and 20°C was at par to 10 and 15°C. It is therefore, proved that *C. flavipes* can be stored at 5°C temperature for 25 days without any detrimental effect on adult emergence. The storage of cocoons for 20 days in 20°C temperature showed that adults were emerged till 15 days of storage and therefore, no data were recorded at and after 20 days of storage. It is apparent that cessation of adult emergence was only found at minimum temperature of 5°C, and for 30 days. Storage of cocoons for longer duration with increased temperature do not inhibit the growth and development. The results of present finding provide empirical evidence that *C. flavipes* can be stored for 15 days at 20°C temperature without any detrimental effect on adult emergence. *C. flavipes* was successfully stored as cocoons at 5°C temperature for 20 days, after which emergence declined considerably. The highest per cent adult emergence occurred at 20°C. This may be due to the fact that 20°C is the temperature closest to the development threshold of *C. flavipes.*

The effect of temperature on life history parameters of insects such as longevity and fecundity has been intensively studied (Mbapila, 1997, Rahim *et al*., 1991). Getu *et al.*, (2003 and 2004) reported differences in longevity and fecundity in Indian and Pakistan populations of *C. flavipes* at different temperatures. Likewise, investigating the impact of cold storage on *Trichogramma spp.* clearly demonstrated that longer storage times accompanied with lower temperatures adversely influenced adult emergence (Jalali and Singh, 1992, Pitcher *et al.*, 2002, Rundle *et al.*, 2004 and Lopez and Botto, 2005).

5.3.2 Sex ratio

The effect of temperature during storage of cocoons of *C. flavipes* was recorded in the form of sex ratio of emerged adults. The data recorded are presented in Table 16 and depicted in Fig.11 which showed that low temperature (5°C) has

significant effect on the sex ratio, 0.24 to 0.39 at different days of storage. Highest sex ratio (0.85) was observed when cocoons were stored for 10 days at 20°C temperature followed by 0.82 at 20°C for 15 days. The storage of cocoons at 10°C limited the sex ratio from 0.51 to 0.60 while at 15°C it ranged from 0.68 to 0.76. It clearly indicated that storage of cocoons of *C. flavipes* at 5°C has adverse effect on the sex ratio.

5.3.3 Cocoon formation

The adults emerged after storage of cocoons at different temperatures was kept for parasitization and thus cocoons formed in F_1 generation are presented in Table 17 and depicted in Fig. 12. The data clearly showed that maximum cocoons (47.08) were formed from the adults which were emerged from the cocoons stored for 10 days at 20°C. The emerged adults from stored cocoons at low temperature (5°C) inhibited the growth and development and 20.2, 17.61, 10.53, 8.54 and 3.39 cocoons formed which were stored for 10, 15, 20, 25 and 30 days respectively. Similar observations were recorded in the storage at 10°C. So a little information is available about the overwintering strategy of *C. flavipes* although such information could be used for enhancing parasitoid efficiency as a biological control agent against the maize stem borers and influences its geographical distribution and establishment of population in countries where the *C. partellus* causes damage to maize. The storage of bioagent at low temperature has varied effects on the adult emergence, sex ratio and F_1 progeny. The present investigation resembles with the work of earlier researchers. Mbapila and Overholt (2001) reported that the development of *Cotesia spp.* from oviposition to cocoon formation and adult emergence was inversely related to temperature. Jiang *et al.* (2004) suggested that sex ratio of *C. flavipes* varied from male to female biased with increase in temperature. Tanwar (2004) reported no population of *C. flavipes* was found tolerant to low temperature.

Many studies on cold storage of hymenopteran parasitoids have focused on endoparasitoids, which are stored within their host larvae (Bayrama *et al.* 2005; Pandey and Johnson, 2005). However, even if parasitoids are protected within host tissues they often experience detrimental effects due to cold storage (Ozder, 2004; Pandey and Johnson, 2005).

In contrary to this, the storage of parasitized eggs by *Trichogramma chilonis* Ishii could be stored for 20 days in the refrigerator without adverse effect on the adult emergence, their parasitization efficiency and sex ratio (Singh, 1997). Similarly, Khosa and Brar (2000) reported that *T. chilonis* could be stored in the refrigerator and

successfully utilized for 23 days without adversely affecting their emergence and parasitization efficiency. Bayrama *et al.* (2005) reported that storage had a significant adverse effect on mean adult emergence of *Telenomus busseolae* Gahan F_1 progeny sex ratio of the parasitoid became more male biased with increasing length of storage treatments. Luczynski *et al.* (2007) reported that adult emergence of *Encarsia formosa* Gahan was prevented at temperatures below 10°C although the pupae continued to develop even at 4°C. Carvalho *et al.* (2008) reported that stored pupae of *C. flavipes* in refrigerator temperature for 5 days do not affect its development. Fatima *et al.* (2009) reported that pupae of *C. flavipes* irradiated at 20 GY could be stored for 2 months at 10°C without apparent loss of quality.

6. SUMMARY

The results obtained under the present study "Investigations on damaging potential of *Chilo partellus* Swinhoe and standardization of multiplication technique of *Cotesia flavipes* Cameron in Southern Rajasthan" are summarized below:

The data recorded on Leaf Injury Rating (LIR) during 2008 and 2009 in HQPM-1 and African tall clearly showed that plant can withstand the infestation of certain number of released larvae which varied according to the resistance of the plant. It is apparent from the data that release of maximum number of 32 larvae / plant, resulted in highest LIR (8.92 and 8.89 in HQPM-1 and 9.00 in African tall in 2008 and 2009, respectively). The LIR observed after release of 24 and 28 larvae / plant in HQPM-1 was 6.87 and 7.93 in 2008 and 6.76 and 7.98 in 2009, respectively while 8.93 and 9.00 in 2008 and 8.95 and 9.00 in 2009 respectively in African tall. Minimum LIR, (1.73) in HQPM-1 was obtained with release of 4 larvae / plant while 4.23 was in African tall. Minimum number of larvae released at 4 / plant, resulted in 1.73 LIR in HQPM-1 while it was 4.23 in African tall. The increased in the number of larvae released from 12 to 20 in HQPM-1 resulted in varied LIR from 3.81 to 5.81 and 3.94 to 5.90 during 2008 and 2009, respectively and 6.16 to 7.59 and 6.67 to 8.37 in 2008 and 2009 respectively in African tall.

The data revealed that plant height in HQPM-1 was varied from 155.85 to 33.79 cm in 2008 and 152.95 to 31.52 cm in 2009 after the release of 4 to 32 larvae / plant whereas in African tall it ranged from 261.94 to 17.49 cm in 2008 and 263.75 to 19.36 cm in 2009. It is also apparent from the table that increase in release rate of neonate larvae of *C. partellus* from 4 to 32 larvae / plant significantly decreased the plant height.

The data on tunnel numbers showed that maximum tunnel numbers, 1.40 and 1.33 / plant, were observed in HQPM-1 during 2008 and 2009 respectively with 24 larvae / plant while in African tall it was 2.37 and 2.36 in 2008 and 2009 respectively with 16 larvae / plant. Minimum tunnel number (0.63 and 0.59 / plant) was recorded during 2008 and 2009 respectively in HQPM-1 after release of 4 larvae / plant while in African tall it was 0.90 and 1.10 in 2008 and 2009, respectively.

Tunnel length in HQPM-1 varied from 0.22 to 9.29 cm in 2008 and 0.23 to 8.43 cm in 2009, respectively whereas in African tall it ranged from 0.00 to 15.32 cm in 2008 and 0.00 to 15.19 cm in 2009, respectively after the release of 4 to 32 larvae /

plant. It shows the positive relationship of tunnel length with release rate. The comparison of tunnel length of HQPM-1 and African tall clearly indicated that the resistance potential of cultivar where longest tunnel length was recorded with 20 larvae / plant while in African tall, longest tunnel length was recorded with 16 larvae / plant during both the years.

The yield obtained from HQPM-1 and African tall showed that release of 4 larvae / plant resulted in maximum yield, 131.28 and 127.41 g / plant in HQPM-1 during 2008 and 2009 respectively. Release of higher number of larvae i.e. 28 and 32 / plant gave almost negligible yield. In African tall maximum yield 100.03 g / plant was obtained in 2008 and 98.74 g in 2009 after the release of 4 larvae / plant. It is also visible from the both years data that no yield was obtained after the release of 24, 28 and 32 larvae / plant. The comparison of yield data of two years for HQPM-1 and African tall clearly shows that the difference in the resistance potential to maize stem borer. The release of 24 to 32 larvae / plant in African tall destroyed the plant completely and no yield could recorded while in HQPM-1 it ranged from 53.34 to 7.58 and 54.39 to 7.10 g / plant in 2008 and 2009 respectively.

The correlation between yield and the combined effect of independent variables *viz.*, LIR, plant height, tunnel number and tunnel length on yield during both the years is highly significant. Correlation between LIR and yield in test corn showed highly significant negative correlation in HQPM-1 (r = -0.983 and -0.982) and in African tall (r =-0.945 and -0.989) during both the years which indicated that increase in the LIR decreased the yield.

Plant height and tunnel number in HQPM-1 and African tall showed positive correlation but non significant in HQPM-1 while significant in African tall (r = 0.740 and 0.740 in 2008 and 2009, respectively).

The observation recorded on plant height and tunnel length showed positive correlation but non significant in HQPM-1 during 2008 and 2009 while significant in African tall being r = 0.698 and 0.985 during 2008 and 2009 respectively. This showed that the plant height in HQPM-1 was not affected much by tunnel length while in African tall, plant height was drastically reduced with the increase in tunnel length.

The data obtained on plant height and yield of HQPM-1 and African tall showed highly significant positive correlation wherein, r = 0.978 and 0.985 was in HQPM-1 and 0.839 and 0.907 in African tall during 2008 and 2009, respectively. The correlation between tunnel number and yield as well as tunnel length and yield was

found non significant but positive in HQPM-1 and in African tall during 2008 and 2009, respectively.

The data obtained on the preference of larval age for maximum offspring of *C. flavipes* showed that increase in the age of larvae of *C. partellus* gave more parasitization and number of cocoons and thus leads to more offspring production as well as significant positive relationship between age of host larvae and number of cocoons produced. The 17 to 20 days old larvae of *C. partellus* were most preferred with the maximum parasitization (82.61 and 82.46 per cent, respectively) with significant maximum number of cocoons (43.09 and 42.70 respectively) while maximum sex ratio 0.86 to 0.88 was obtained with 8 to 14 days old larvae. It is also clear that 5 days old larvae were not preferred for parasitization and henceforth no cocoon formation and adult emergence was observed.

The results obtained on parasitization in different sized ovipositional chambers showed that maximum parasitization (89.56 per cent) was recorded in test tube followed by 88.05, 76.53 and 66.79 per cent in pearl pet jar of 500, 1000 and 2000 g, respectively. Similarly, maximum cocoons (37.53) were recorded in test tube while minimum (35.20) in pearl pet jar of 2000 g. The sex ratio recorded in test tube was statistically superior to pearl pet jar of 1000 and 2000 g but at par with pearl pet jar of 500 g. The increase of larval density from 2 to 5 larvae to a single pair of adult parasitoid in different ovipositional chambers showed the distribution of egg laid which resulted in decreased parasitization, number of cocoons formed and sex ratio.

Adult emergence from cocoons of *C. flavipes* varied with storage time and temperature. It is clear from the data that storage of cocoons for 10 days at different test temperatures did not affected adult emergence significantly, 95.96 to 97.58 per cent and all the treatments were at par. Similarly, storage of cocoons for 15 days at different test temperatures also resulted in good adult emergence ranged from 95.22 to 98.46 per cent where adult emergence at 5°C was statistically at par to 10 and 15°C while 20°C was at par to 10 and 15°C.

It is visible from the data that low temperature (5°C) significantly affects on the sex ratio (0.24 to 0.39) at different days of storage. Highest sex ratio (0.85) was observed when cocoons were stored for 10 days at 20°C followed by 0.82 at 20°C for 15 days. The storage of cocoons at 10°C reduced the sex ratio from 0.51 to 0.60 while at 15°C it ranged from 0.68 to 0.76. Maximum cocoons (47.08) were formed from the adults which were emerged from the cocoons stored for 10 days at 20°C while 5°C temperature inhibited the growth and development with least number of cocoons.

Table 11. Preference of larval age for maximum offspring of *C. flavipes*

Days old larvae	Per cent parasitization	Number of cocoons per larva	Sex ratio
T_1 = 5	0.00 (0.64)**	0.00 (0.71)*	0.00 (5.86) **
T_2 = 8	34.79 (35.76) **	12.50 (3.54)*	0.86 (68.38) **
T_3 = 11	45.41 (42.42) **	16.19 (4.02)*	0.88 (70.92) **
T_4 = 14	72.82 (59.38) **	27.33 (5.22)*	0.88 (69.82) **
T_5 = 17	82.61 (66.56) **	43.09 (6.56)*	0.82 (65.93) **
T_6 = 20	82.46 (65.33) **	42.70 (6.53)*	0.83 (66.20) **
SEm±	1.00	0.13	1.02
CD (5%)	2.10	0.27	2.14
CV %	3.17	4.01	2.51

* Figures in parentheses represent retransformed square root values
**Values in parentheses represent arc sine transformation

Table 13. Effect of different ovipositional chambers and larval density on number of *C. flavipes* cocoons per larva of *C. partellus*

Specification of ovipositional chambers	Mean number of cocoons of *C. flavipes*

Name	Size	Capacity	Larval density in ovipositional chamber				
			One larva	Two larvae	Three larvae	Four larvae	Five larvae
T_1 = Test tube	**12×2.5 cm^2**	**-**	37.53 (6.13)	19.21 (4.38)	12.29 (3.51)	09.05 (3.01)	07.03 (2.65)
T_2 = Pearl pet jar	**11×8 cm^2**	**500 g**	37.13 (6.09)	18.58 (4.31)	12.53 (3.54)	08.91 (2.98)	07.61 (2.75)
T_3 = Pearl pet jar	**16x10 cm^2**	**1000 g**	36.28 (6.02)	18.48 (4.29)	11.81 (3.43)	09.81 (3.13)	07.11 (2.66)
T_4 = Pearl pet jar	**23x12 cm^2**	**2000 g**	35.20 (5.93)	18.71 (4.32)	12.45 (3.53)	08.78 (2.96)	06.65 (2.58)
SEm±			0.08	0.12	0.07	0.06	0.10
CD (P = 0.05)			0.17	0.26	0.14	0.12	0.21
CV %			2.09	4.46	3.05	3.08	5.81

Values in parentheses represent retransformed root square values

Table 14. Effect of different ovipositional chambers and larval density of *C. partellus* on sex ratio of *C. flavipes*

Specification of ovipositional chambers			Sex ratio of *C. flavipes*				
Name	**Size**	**Capacity**	**Larval density in ovipositional chamber**				
			One larva	**Two larvae**	**Three larvae**	**Four larvae**	**Five larvae**

T_1 = Test tube	**12×2.5 cm^2**	**-**	0.80 (63.60)	0.82 (64.77)	0.83 (65.99)	0.82 (64.77)	0.80 (63.60)
T_2 = Pearl pet jar	**11×8 cm^2**	**500 g**	0.78 (62.19)	0.80 (63.60)	0.78 (62.19)	0.80 (63.60)	0.80 (63.60)
T_3 = Pearl pet jar	**16x10 cm^2**	**1000 g**	0.72 (58.06)	0.74 (59.49)	0.75 (60.04)	0.71 (57.42)	0.69 (55.93)
T_4 = Pearl pet jar	**23x12 cm^2**	**2000 g**	0.53 (46.84)	0.70 (56.93)	0.65 (53.74)	0.68 (55.55)	0.62 (52.06)
SEm±			1.16	1.03	1.28	0.92	1.12
CD (P = 0.05)			2.45	2.19	2.70	1.95	2.37
CV %			3.17	2.67	3.34	2.41	3.01

Values in parentheses represent arc sine transformation

Table 15. Effect of temperature during storage and storage period on adult emergence of *C. flavipes*

Temperature regimes	Adult emergence (%) after storage for different period (days)				
	10	**15**	**20**	**25**	**30**
T_1 = 5°C	96.44 (79.19)	95.22 (77.42)	90.94 (72.50)	85.56 (67.76)	68.90 (56.11)
T_2 = 10°C	95.96 (78.48)	96.64 (79.56)	92.96 (74.63)	83.42 (65.98)	0.00 (0.64)
T_3 = 15°C	96.76 (79.69)	97.46 (80.93)	93.20 (74.99)	0.00 (0.64)	0.00 (0.64)
T_4 = 20°C	97.58 (81.65)	98.46 (83.31)	0.00 (0.64)	0.00 (0.64)	0.00 (0.64)
SEm±	1.39	1.23	0.76	0.88	0.33
CD (P = 0.05)	2.94	2.60	1.61	1.87	0.70
CV %	2.75	2.42	2.16	4.12	3.61

Values in parentheses represent arc sine transformation

Table 16. Effect of temperature during storage and storage period on sex ratio of *C. flavipes*

Temperature regimes	Proportion of female to male at different storage period (days)				
	10	**15**	**20**	**25**	**30**
T_1 = 5°C	0.28 (31.68)	0.26 (30.91)	0.38 (37.91)	0.24 (29.60)	0.39 (38.76)
T_2 = 10°C	0.51 (45.57)	0.54 (47.41)	0.60 (50.66)	0.54 (47.41)	0.00 (6.42)
T_3 = 15°C	0.68 (55.56)	0.71 (57.30)	0.76 (60.69)	0.00 (6.42)	0.00 (6.42)
T_4 = 20°C	0.85 (67.07)	0.82 (65.07)	0.00 (6.42)	0.00 (6.42)	0.00 (6.42)
SEm±	0.94	0.81	1.07	0.49	0.47
CD (P = 0.05)	1.99	1.71	2.26	1.04	0.99
CV %	2.96	2.54	4.33	3.45	5.08

Values in parentheses represent arc sine transformation

Table 12. Effect of different ovipositional chambers and larval density on parasitization of *C. partellus* by *C. flavipes*

Specification of ovipositional chambers	**Mean parasitization (%) by *C. flavipes***

Name	Size	Capacity	Larval density in ovipositional chamber				
			One larva	Two larvae	Three larvae	Four larvae	Five larvae
T_1 = Test tube	**12×2.5 cm^2**	**-**	89.56 (71.22)	82.98 (65.67)	75.45 (60.30)	68.02 (55.56)	54.55 (47.61)
T_2 = Pearl pet jar	**11×8 cm^2**	**500 g**	88.05 (69.80)	77.89 (61.97)	71.78 (57.92)	66.09 (54.39)	57.44 (49.28)
T_3 = Pearl pet jar	**16x10 cm^2**	**1000 g**	76.53 (61.02)	70.97 (57.40)	63.56 (52.87)	60.56 (51.00)	56.27 (48.61)
T_4 = Pearl pet jar	**23x12 cm^2**	**2000 g**	66.79 (54.81)	64.04 (53.16)	53.02 (46.73)	49.98 (44.99)	42.24 (40.54)
SEm±			0.81	0.90	0.71	0.54	0.92
CD (P = 0.05)			1.72	1.90	1.51	1.14	1.96
CV %			1.99	2.38	2.07	1.66	3.14

Table 17. Effect of temperature and storage period on number of cocoons of *C. flavipes*

Temperature regimes	Mean number of cocoons after different storage period (days)				
	10	**15**	**20**	**25**	**30**
T_1 = 5°C	20.20	17.61	10.53	8.45	3.39
	(4.49)	(4.19)	(3.32)	(2.99)	(1.97)
T_2 = 10°C	28.84	18.97	12.23	8.33	0.00
	(5.37)	(4.35)	(3.56)	(2.97)	(0.71)
T_3 = 15°C	30.93	17.45	17.40	0.00	0.00
	(5.56)	(4.17)	(4.23)	(0.71)	(0.71)
T_4 = 20°C	47.08	37.17	0.00	0.00	0.00
	(6.86)	(6.09)	(0.71)	(0.71)	(0.71)
SEm±	0.14	0.11	0.10	0.04	0.04
CD (P = 0.05)	0.29	0.24	0.20	0.08	0.08
CV %	3.86	3.81	5.09	3.05	6.10

*Figures in parentheses represent retransformed square root values

Table 7. Correlation matrix between stem borer damage parameters and yield of maize variety HQPM-1 during 2008

Biological Traits	LIR	Plant height	Tunnel number	Tunnel length	Yield
LIR	1	-	-	-	-
Plant height	-0.981**	1	-	-	-
Tunnel number	-0.346	0.499	1	-	-
Tunnel length	-0.106	0.264	0.955**	1	-
Yield	-0.983**	0.978**	0.435	0.221	1

R=0.993**

** Significant at 1% probability level

Table 8. Correlation matrix between stem borer damage parameters and yield of maize variety HQPM-1 during 2009

Biological Traits	LIR	Plant height	Tunnel number	Tunnel length	Yield

LIR	1	-	-	-	-
Plant height	-0.988**	1	-	-	-
Tunnel number	-0.352	0.446	1	-	-
Tunnel length	-0.145	0.237	0.959**	1	-
Yield	-0.982**	0.985**	0.477	0.293	1

R=0.995**

** Significant at 1% probability level

Table 9. Correlation matrix between stem borer damage parameters and yield of maize variety African tall during 2008

Biological Traits	LIR	Plant height	Tunnel number	Tunnel length	Yield
LIR	1	-	-	-	-

Plant height	-0.960**	1	-	-	-
Tunnel number	-0.584	0.740*	1	-	-
Tunnel length	-0.529	0.698*	0.996**	1	-
Yield	-0.945**	0.839**	0.346	0.283	1

R=0.983**

** Significant at 1% probability level

Table 10. Correlation matrix between stem borer damage parameters and yield of maize variety African tall during 2009

Biological Traits	**LIR**	**Plant height**	**Tunnel number**	**Tunnel length**	**Yield**
LIR	1	-	-	-	-
Plant height	-0.950**	1	-	-	-

Tunnel number	-0.531	0.740*	1	-	-
Tunnel length	-0.482	0.985**	0.985**	1	-
Yield	-0.989**	0.907**	0.408	0.364	1

R=0.999**

** Significant at 1% probability level

Table 2. Effect of release of neonate larvae of *C. partellus* on LIR in maize during 2008 and 2009

Larvae / plant	**Mean LIR after 45 days of germination**					
	HQPM-1			**African tall**		
	2008	**2009**	**Pooled**	**2008**	**2009**	**Pooled**
4	1.64	1.82	1.73	4.19	4.28	4.23
8	2.80	2.78	2.79	5.36	5.19	5.28
12	3.81	3.94	3.87	6.16	6.67	6.41
16	4.89	4.86	4.87	6.94	7.66	7.30
20	5.81	5.90	5.85	7.59	8.37	7.98

24	6.87	6.76	6.81	8.93	8.95	8.94
28	7.93	7.98	7.96	9.00	9.00	9.00
32	8.92	8.89	8.91	9.00	9.00	9.00
SEm±	0.288	0.237	0.226	0.241	0.125	0.161
CD (P = 0.05)	0.708	0.691	0.646	0.708	0.364	0.459
CV (%)	10.82	8.82	-	6.74	3.38	-

Table 3. Effect of release of neonate larvae of *C. partellus* on plant height in maize during 2008 and 2009

Larvae / plant	**Mean plant height (cm) at harvest**					
	HQPM-1			**African tall**		
	2008	**2009**	**Pooled**	**2008**	**2009**	**Pooled**
4	155.85	152.95	154.40	261.94	263.75	262.85
8	149.34	145.70	147.52	259.99	255.81	257.90
12	132.94	134.87	133.90	239.21	211.17	225.19
16	116.57	118.36	117.47	189.53	167.08	178.30
20	95.00	92.97	93.98	134.44	36.64	85.54
24	89.74	77.27	83.50	26.78	28.45	27.61
28	46.63	47.42	47.03	25.60	25.02	25.31

32	33.79	31.52	32.66	17.49	19.36	18.42
SEm±	**2.608**	**2.839**	**2.353**	**7.582**	**4.312**	**5.152**
CD (P = 0.05)	**7.672**	**8.29**	**6.715**	**22.29**	**12.586**	**14.702**
CV (%)	**5.09**	**5.67**	**-**	**10.50**	**6.85**	**-**

Table 4. Effect of release of neonate larvae of *C. partellus* on tunnel number in maize during 2008 and 2009

Larvae / plant	**Mean tunnel number at harvest**					
	HQPM-1			**African tall**		
	2008	**2009**	**Pooled**	**2008**	**2009**	**Pooled**
4	0.63	0.59	0.61	0.90	1.10	1.00
8	0.83	0.85	0.84	1.13	1.23	1.18
12	0.90	1.01	0.96	1.67	1.79	1.73
16	0.89	0.94	0.91	2.37	2.36	2.37
20	1.01	1.25	1.13	0.45	0.55	0.50
24	1.40	1.33	1.36	0.10	0.15	0.12
28	0.31	0.33	0.32	0.00	0.00	0.00
32	0.06	0.03	0.05	0.00	0.00	0.00
SEm±	**0.056**	**0.062**	**0.05**	**0.037**	**0.046**	**.036**
CD (P = 0.05)	**0.16**	**0.18**	**0.14**	**0.10**	**0.13**	**0.10**

CV (%)	**14.99**	**15.68**	**-**	**8.98**	**10.32**	**-**

Table 5. Effect of release of neonate larvae of *C. partellus* on tunnel length in maize during 2008 and 2009

Larvae / plant	**Mean tunnel length (cm) at harvest**					
	HQPM-1			**African tall**		
	2008	**2009**	**Pooled**	**2008**	**2009**	**Pooled**
4	2.36	2.06	2.21	4.61	6.14	5.37
8	3.59	3.49	3.54	6.94	6.30	6.62
12	4.26	5.13	4.69	9.88	10.69	10.28
16	4.35	4.58	4.46	15.32	15.19	15.26
20	7.02	8.36	7.69	3.04	0.70	1.87
24	9.29	8.43	8.86	0.41	0.13	0.27
28	0.82	0.38	0.60	0.00	0.00	0.00
32	0.22	0.23	0.23	0.00	0.00	0.00
SEm±	**0.138**	**0.144**	**0.119**	**0.106**	**0.163**	**0.118**
CD (P = 0.05)	**.407**	**0.419**	**0.341**	**0.313**	**.475**	**0.338**
CV (%)	**6.94**	**7.04**	**-**	**4.23**	**6.66**	**-**

Table 6. Effect of release of neonate larvae of *C. partellus* on plant yield (g/plant) in maize during 2008 and 2009

Larvae / plant	Mean plant yield (g/plant) after harvest					
	HQPM-1			African tall		
	2008	2009	Pooled	2008	2009	Pooled
4	131.28	127.41	129.34	100.03	98.74	99.38
8	100.91	100.30	100.60	77.80	75.60	76.70
12	82.10	96.58	89.34	40.62	43.50	42.06
16	74.98	81.44	78.21	12.99	11.00	11.99
20	64.28	69.90	67.09	5.34	5.54	5.44
24	53.34	54.39	53.87	0.00	0.00	0.00
28	15.73	15.95	15.84	0.00	0.00	0.00
32	7.58	7.10	7.34	0.00	0.00	0.00
SEm±	2.284	1.79	1.73	0.859	0.722	0.670
CD (P = 0.05)	6.72	5.22	4.94	2.526	2.108	1.914
CV (%)	6.89	5.18	-	5.80	4.93	-

LITERATURE CITED

Ajala S.O. 1994. Maize *(Zea mays* L.) stem borer *(Chilo partellus* Swinhoe) infestation / damage and plant resistance. *Maydica* **39**: 203-206.

Ajala, S.O., Nour, A.M., Ampong-Nyarko, K. and Odindo, M.O. 2010. Evaluation of maize (*Zea mays* L.) genotypes as a component of integrated stem borer (*Chilo partellus* Swinhoe) management in coastal region of Kenya. *African Journal of Agricultural Research* **5**: 758-763.

Arabjafari, K.H. and Jalali, S.K. 2007. Identification and analysis of host plant resistance in leading maize genotypes against spotted stem borer, *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). *Pak Journal Biological Sciences* **10**: 1885-1895.

Awan, N.A. and Khaliq, A. 2003. Relative resistance of maize stem borer, *Chilo partellus* (Swinhoe) against some maize cultivars. *Pakistan Journal of Biological Sciences* **6**: 142-145.

Barrow, M.R. 1987. The effect of first generation maize stalk borer, *Busseola fuska* (Fuller) (Lepidoptera: Noctuidae) on yield of different maize genotypes. *Journal of Entomological Society of South Africa* **50**: 291-298.

Bayrama, A., Ozcan, H. and Kornosor S. 2005. Effect of cold storage on the performance of *Telenomus busseolae* Gahan (Hymenoptera: Scelionidae), an egg parasitoid of *Sesamia nonagrioides* (Lefebvre) (Lepidoptera: Noctuidae). *Biological Control* **35**: 68-77.

Belay, D. and Foster J.E. 2010. Efficacies of habitat management techniques in managing maize stem borers in Ethiopia. *Crop Protection* **29**: 422-428.

Campos Farinha, A.E. de C. and Chaud Netto, J. 2000. Reproductive biology of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae) V. Evaluation of the number of egg layings, offspring production and sex ratio of the parasitoid according to host size (*Diatraea saccharalis* Fabricius) (Lepidoptera: Pyralidae). *Arquivos do Instituto Biologico Sao Paulo* **67**: 249-252.

Campos Farinha, A.E. de C., Chaud Netto, J. and de C. Campos Farinha, A.E. 1998a. Reproductive biology of *Cotesia flavipes* (Cameron). II. Effect of multiple matings on the number of layings, offspring and sex ratio of parasitoids that emerge from *Diatraea soccharalis* (F.). *Arquivos do Instituto Biologico Sao Paulo* **65**: 57-61.

Campos Farinha, A.E. de C., Chaud Netto, J. and de C. Campos Farinha, A.E. 1998b. Reproductive biology of *Cotesia flavipes* (Cam.). III. Mutual interference: females mated to one and two males. *Arquivos do Instituto Biologico Sao Paulo*. **65**: 119-121.

Campos-Farinha, A.E. de C.; Chaud Netto, J. and Gobbi, N. 2000. Reproductive biology of *Cotesia flavipes* (Cameron) (Hymenoptera: Braconidae). IV. Discrimination between parasitized and unparasitized larvae of *Diatraea saccharalis* Fabricius (Lepidoptera: Pyralidae), developmental time and sex ratio of the parasitoids. *Arequivos-do-Instituto Biological Sao Paulo* **67**: 229-234.

Cardwell, K.F., Schulthess, F., Ndemah, R. and Ngoko, Z. 1997. A systems approach to assess crop health and maize yield losses due to pests and diseases in Cameroon. *Agriculture, Ecosystems & Environment* **65**: 33-47.

Carvalho, J.S.,Vacari, A.M., Bortoli, S.A and Viel, S.R. 2008. Efeito do armazenamento de pupas de *Cotesia flavipes* (Cameron, 1891) (Hymenoptera: Braconidae) em baixa temperature. *Boletín de Sanidad Vegetal, Plagas* **34**: 21

Chatterji, S.M., Panwar, V.P.S., Siddiqui, K.H., Young, W.R. and Marwaha, K.K. 1970. Field screening of some promising maize germplasm against *Chilo partellus* Swinhoe under artificial infestation. *Indian Journal of Entomology* **32**: 167-170.

Chatterji, S.M., Young, W.R., Sharma, G.C., Sayi, I.V., Chahal, B.S., Khare, B.P., Rathore, Y.S., Panwar, V.P.S. and Siddiqui, K.H. 1969. Estimation of loss in yield of maize due to insect pests with special reference to borers. *Indian Journal of Entomology* **31**: 109-115.

Chavan, B.P., Khot. R.B. and Harer, P.N. 2007. Reaction of maize germplasm to maize stem borer, *Chilo partellus* Swinhoe. *Journal of Entomological Research* **31**: 238-250.

Chen, W.L., Leopold, R.A. and Harris, M.O. 2008. Cold storage effect on maternal and progeny quality of *Gonatocerus ashmeadi* Girault. *Biological Control* **46**: 122-132.

Dass, S., Mehla J.C., Moudgal R.K., Dhanju K.S., Dharam Pal, Singh D.P. and Vineet Kumar. 2006. Identification of morphological traits in maize for its least susceptibility to *Chilo partellus*. *Annals of Plant Protection Sciences* **14**.

De Groote, H., W. Overholt, J.O. Ouma and S. Mugo. 2003. "Assessing the impact of Bt maize in Kenya using a GIS model." Paper presented at the International Agricultural Economics Conference, Durban, August 2003.

Divyal, K., Marulasiddesa, K.N., Karupanidhi, K. and Sankar, M. 2009. Population dynamics of stem borer, *Chilo partellus* (Swinhoe) and its interaction with natural enemies in sorghum. *Indian Journal of Science and Technology* **3**: 1-2.

Fatima, B., Nazir, A., Raza Muhammad, M., Moula, B. and Qadeer Ahma. 2009. Enhancing biological control of sugarcane shoot borer, *Chilo infuscatellus* (Lepidoptera: Pyralidae), through use of radiation to improve laboratory rearing and field augmentation of egg and larval parasitoids. *Biocontrol Science and Technology* **19**: 277-290.

Foerster and Foerster. 2009. Effects of Temperature on the immature development and emergence of five species of *Trichogramma*. *BioControl* **54**: 445-450.

Getu, E., Overholt, W.,A., Kairu, E. and Omwega, C.O. 2003. Evidence of the establishment of *Cotesia flavipes* (Hymenoptera: Braconidae), a parasitoid of cereal stemborers and its host range expansion in Ethiopia. *Bulletin of Entomological Research* **93**: 125-129.

Getu, E., William A. Overholt and Kairu, E. 2004. Comparative studies on the influence of relative humidity and temperature on life table parameters of two populations of *Cotesia flavipes* (Hymenoptera: Braconidae). *Biocontrol Science and Technology* **14**: 595-605.

Govt. of Rajasthan. 2008. Vital Agriculture Statistics. Statistical Cell, Directorate of Agriculture, Pant Krishi Bhawan, Jaipur (www.rajasthankrishi.gov.in)

Hackermann, J., Anja, S. Rott, Kathrin Tschudi-rein and Silvia Dorn. 2008. Cold stored ectoparasitoid of *Cydia* fruit moths released under different temperature regimes. *BioControl* **53**: 857-867.

Hailemichael, Y., Schulthess, F., Smith, J., Overholt, W., and Chabi-Olaye, A. 2008. Resource Allocation and Bionomics of Indigenous and Exotic *Cotesia* (Hymenoptera: Braconidae) Species Reared on *Sesamia calamistis*. *Bulletin of Entomological Research* **98**: 405-415.

http:// www.business_standard.com.

Jalali, S.K. and Singh, S.P. 1992. Biology and feeding potential of *Curinus coeruleus* (Mulsant) and *Chrysoperla carnea* (Stephens) on subabul psyllid, *Heteropsylla cubana* Crawford. *Journal of Insect Science* **5**: 89-90.

Jalali, S.K. and Singh, S.P. 2002. Selection and host age preference of natural enemies of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). *Pest Management and Economic Zoology* **10**: 149-157.

Jalali, S.K. and Singh, S.P. 2003. Determination of release rates of natural enemies for evolving bio-intensive management of *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae). *Shashpa* **10**: 151-154.

James, C. 2003. Global review of commercialized transgenic crop: 2002 features: *Bt Maize ISAAA* **29**: 182.

Jiang, N., Setamou, M., Ngi, Song, A.J. and Omwega, C.O. 2004. Performance of *Cotesia flavipes* (Hymenoptera: Braconidae) in parasitizing *Chilo partellus* (Lepidoptera: Pyralidae) as affected by temperature and host stage. *Biological Control* **31**: 155-164.

Jindal, J. and Hari N.S. 2008. Studies on Components of Resistance in Maize Genotypes to *Chilo partellus* (Swinhoe). *Indian Journal of Entomology* **70**: 314-318.

Kakar, A.S., Kakar, K.M., Khan, M.T, Shawani, M.I. and A. B. Tareen, 2003. Studies on varietal screening of maize against maize stem borer, *Chilo partellus* (Swinhoe). *Journal of Biological Sciences* **3**: 233-236.

Kalode, M.B. and Pant, N.C. 1966. Studies on the susceptibility of different varieties of sorghum, maize and bajra to *Chilo zonellus* (Swinhoe) under field and cage conditions and the methods of determining it. *Indian Journal of Entomology* **28**: 448-464.

Karamaouna, F. and Copland, M.J. 2009. Fitness and life history parameters of *Leptomastix epona* and *Pseudophycus flavidulus*, two parasitoids of the obscure Mealybug *Pseudococcus viburni*. *BioControl* **54**: 65-76.

Kfir, R., Overholt, W.A., Khan, Z.R. and Polaszek, A. 2002. Biology and management of economically important lepidopteran cereal stem borers in Africa. *Annual Review of Entomology* **47**: 701-731.

Khambadkar, H.U., Aherkar, S.K., Dhande, V.R. and Deshmukh, P.B. 2003. Parasitization studies of *Apanteles flavipes* on *Chilo partellus* in sorghum. *Insect Environment* **9**: 181-182.

Khosa, S.S. and Brar, K.S. 2000. Effect of storage on the emergence and parasitization efficiency of laboratory reared and field collected populations of *Trichogramma chilonis* Ishii. *Journal of Biological Control* **14**: 71-74.

Kumar, H. 1994. Field resistance in maize cultivars to stem borer *Chilo partellus*. *Annals of Applied Biology* **124**: 333-339.

Kumar, H.1997a. Resistance in maize to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae): Role of stalk damage parameters and biological control. *Crop protection* **16**: 375-381.

Kumar, H. 1997b. Resistance in maize to *Chilo partellus* (Swinhoe) (Lepidoptera: Pyralidae): an overview. *Crop Protection* **16**: 243-250.

Kumar, H. and Asino, G.O. 1994. Grain yield losses in maize (*Zea mays* L.) genotypes in relation to their resistance against *Chilo partellus* (Swinhoe) infestation at anthesis. *Crop Protection* **13**: 136-140.

Kumar, H. and Mihm, J.A. 1996. Resistance in maize hybrids and inbreds to first-generation southwestern corn borer, *Diatraea grandiosella* (Dyar) and sugarcane borer, *Diatraea saccharalis* Fabricius. *Crop Protection* **15**: 311-317.

Lopez, S.N. and Botto E. 2005. Effect of cold storage on some biological parameters of *Eretmocerus corni* and *Encarsia formosa* (Hymenoptera: Aphelinidae). *Biological Control* **33**: 123-130.

Luczynski, A., Nyrop, J.P. and Shi, A. 2007. Influence of cold storage on pupal development and mortality during storage and on post storage performance of *Encarsia formosa* and *Eretmocerus eremicus* (Hymenoptera: Aphelinidae). *Biological control* **40**: 107-117.

Mathur, L.M.L. 1991. Genetics of insect resistance in maize. In maize genetics perspectives: *Entomologia Experimentalis Et Applicata* **98**: 211-217.

Mbapila J.C. 1997. Comparative adaption of *Cotesia flavipes* Cameron and *Cotesia sesamiae* (Cameron) (Hymenoptera: Braconidae) to *Chilo partellus* Swinhoe (Lepidoptera: Pyralidae) on the Kenya coast. Ph. D. thesis, University of Dares-Salaam.

Mbapila, J.C. and Overholt, W.A. 2001. Comparative development, longevity and population growth of exotic and native parasitoids of lepidopteran cereal stem borers in Kenya. *Bulletin of Entomological Research* **91**: 347-354.

Mohyuddin, A.I. and Inayatullah, C. 1981. Host selection and strain occurrence in *Apanteles flavipes* (Cameron) (Hymenoptera: Braconidae) and its bearing on biological control of gramineous stem borer. *Bulletin of Entomological Research* **71**: 575-581.

Oerka, E.C. 2002. Crop losses due to insect pests in major crops. In: CAB International crop protection compendium 2002. Economic Impact. CAB International, Wallingford, U.K.

Overholt W. A., Ochieng J. O., Lammers P. and Ogedah K. 1994. Rearing and field release methods for *Cotesia flavipes* Cameron (Hymenoptera: Braconidae), a parasitoid of tropical gramineous stem borers. *Insect Science and its Application* **15**: 253-259.

Ozder N. 2004. Effect of different cold storage periods on parasitization performance of *Trichogramma cacoeciae* (Hymenoptera: Trichogrammatidae) on eggs of *Ephestia kuehniella* (Lepidoptera, Pyralidae). *Biocontrol Science and Technology* **14**: 441-447.

Padmaja, P.G. and Prabhakar, M. 2004. Natural parasitisation of spotted stem borer, *Chilo partellus* (Swinhoe) on sweet sorghum in Andhra Pradesh. *Indian Journal of Entomology* **66**: 285-286.

Pandey R. R. and Johnson M. W. 2005. Effects of cool storage on *Anagyrus ananatis* Gahan (Hymenoptera: Encyrtidae). *Biocontrol* **35**: 9-16.

Panwar V. P. S. 2005. Management of maize stalk borer,. *Chilo* partellus (Swinhoe) in maize. In. Stresses on Maize in the Tropics (Edited by Zaidi, P.H. and Singh, N.N.): 376–395.

Panwar, V.P.S., Siddiqui, K.H., Marwaha, K.K. and Sarup, P. 1979. Location of sources of resistance to the stalk borer, *Chilo partellus* (Swinhoe) amongst 'Introduction Nursery' comprising exotic and indigenous maize germplasms. *Journal of Entomological Research* **3**:191-195

Panwar, V.P.S., Singh, N.N., Vasal, S.K. and Bergvinson, D. 2001. Resistance of exotic germplasms to the Asian maize stalk borer, *Chilo partellus* (Swinhoe). *Indian Journal of Genetics and Plant Breeding* **61**: 356-357.

Parminder, Kumar, Maninder, Shenhmar and Brar, K.S. 2005. Effect of low temperature storage on the efficiency of three species of trichogrammatids. *Journal of Biological Control* **19**: 17-22.

Pereira, F.F., Zanuncio, J.C., Serrão, J.E., Pastori, P.L. and Ramalho, F.S. 2009. Reproductive Performance of *Palmistichus elaeisis* Delvare and Lasalle (Hymenoptera: Eulophidae) with Previously Refrigerated Pupae of *Bombyx mori* L. (Lepidoptera: Bombycidae). *Brazilian Journal of Biology* **69**: 865-869.

Pitcher, S.A., Hoffmann, M.P., Gardner, J., Wright, M.G. & Kuhar, T.P. 2002. Effect of cold storage on emergence and fitness of *Trichogramma ostriniae* (Hymenoptera: Trichogrammatidae) reared on *Sitotroga cerealella* (Olivier) (Lepidopera: Gelechiidae) eggs. *BioControl* **47**: 525-535.

Rahim, A., Asghar, A.H. and Alam, N.K. 1991. Effect of temperature and relative humidity on longevity and evelopment of *Ooencyrtus papilionis* Ashmead (Hymenoptera: Eulophidae), a parasite of the Sugarcane pest, *Pyrilla perpusilla* Walker (Homoptera: Cicadellidae). *Environmental Entomology* **20**: 774-775.

Reddy, D.B. 1968. Plant protection in India. Allied publisher, Calcutta 109-114.

Reddy, M.L. 2003. Evaluation of maize germplasms to identify resistant source to *Chilo partellus. Journal of Research ANGRU* **31**: 100-102.

Regiane, Cristina, Oliveira, F.B., Jose, Roberto, Postali, Parra and Adeney, Freitas, Bueno. 2009. Biological characteristics and thermal requirements of a Brazilian strain of the parasitoid *Trichogramma pretiosum*. *Biological Control* **51**: 355-361.

Rundle, B., Thomson, J., Linda, J. and Hoffmann, A.A. 2004. Effects of cold storage on field and laboratory performance of *Trichogramma carverae* (Hymenoptera: Trichogrammatidae) and the response of three *Trichogramma* spp. (*T. carverae*, *T.* nr. *brassicae*, and *T. funiculatum*) to cold. *Journal of Economic Entomology* **97**: 213-221.

Sait, S.M., Begon, M., and Thompson, D.J. 1997. Factors affecting host selection in an insect host-parasitoid interaction. *Ecological Entomology* **22**: 225-230.

Sarup, P., Marwaha, K.K., Panwar, V.P.S. and Siddiqui, K.H. 1977. Studies on insect plant relationship evaluation of 'introduction nursery' for resistance to the maize stalk borer, *Chilo partellus* (Swinhoe) under artificial infestation. *Journal of Entomological Research* **1**: 151-157.

Sarup, P., Marwaha, K.K., Panwar, V.P.S. and Siddiqui, K.H. 1978. Evaluation of some exotic and indigenous maize germplasms for resistance to *Chilo partellus* (Swinhoe) under artificial infestation. *Journal of Entomological Research* **2**: 98-105.

Saskya, Van, Nouhuys and Guangchun, Lei. 2004. Parasitoid-host metapopulation dynamics: the causes and consequences of phenological asynchrony. *Journal of Animal Ecology* **73**: 526-535.

Seshu Reddy, K.V. and Sum, K.O.S. 1992. Yield-infestation relationship and determination of economic injury level of the stem-borer, *Chilo partellus* (Swinhoe) in three varieties of maize, *Zea mays* L. *Maydica* **37**: 371-376.

Sharma, H.C., Dhillon, M. K., Pampapathy, G. and Reddy, B.V.S. 2007. Inheritance of resistance to spotted stem borer, *Chilo partellus* in sorghum, *Sorghum bicolor*. *Euphytica* **156**: 117–128.

Shekharappa and Kulkarni, K.A. 2003. Host age preference of *Cotesia flavipes* Cameron, a larval parasitoid of *Chilo partellus* (Swinhoe). Biological control of lepidopteran pests. Proceedings of the symposium of biological control of lepidopteran pests, July 17-18, 2002, Bangalore, India: 91-93.

Shi, Z., Liu S. and Yuan L. 2002. *Cotesia plutellae* Parasitizing *Plutella xylostella*: host-age dependent parasitism and its effect on host development and food consumption. *Biocontrol* **47**: 499-511.

Siddiqui, K.H. and Marwaha, K.K.1994. Distribution life cycle and nature of damage of some insect pests of Maize. The Vistas of maize entomology in India. Kalyani Publishers, New Delhi, India. 17-19.

Singh, J and Sajjan, S.S. 1982. Losses in maize yield due to different grades (1-9 scales) caused by maize stem borer. *Indian Journal of Entomology* **44**: 41-48.

Singh, R., Prasad, A.R. and Acharya, R.C. 1962. Studies on the adequacy of visual ratings for infestation and relation between per cent infestation of maize plants and population of maize borer under natural infestation condition. *Bihar Academic Agriculture Sciences* **11**: 1-8.

Singh, S.P. 1997. Field efficacy of some bio-pesticides against shoot fly and stem borer in forage sorghum. *Forage Research* **24**: 177-178.

Singh, S.R., Veda Moorthy, G., Thobbi, V.V., Jotwani, M.G., Young, W.R., Balan, J.S., Srivastava, K.P., Sandhu, G.S. and Krishnananda, N. 1968. Resistance to stem borer, *Chilo zonellus* (Swinhoe) and stemfly, *Atherigona varia soccata* in the world sorghum collection in India. *Entomological Society of India* **7**: 1-79.

Songa, J.M., Zhou, G. and W.A. Overholt, 2001. Relationship of stem borer damage and plant physical condition to maize yield in a semi arid zone of Eastern Kenya. *Insect Science and Its Application* **21**: 243-249.

Srikanth, J., Easwaramoorthy, S., Kumar, R. and Shanmugasundaram, M. 2000. Patterns of laboratory parasitization rates of *Cotesia flavipes* Cameron (Hymenoptera: Braconidae) in borers of sugarcane and sorghum. *Insect Science and Its Application* **20**: 195-202.

Tanwar, R.K. 2004. Variability and reproductive compatibility among populations of *Cotesia flavipes* from different agro-climatic regions. *Annals of Plant Protection Sciences* **12**: 16-20.

Tillman, P.G. 2001. Factors affecting Parasitization of *Spodoptera exigua* (Lepidoptera: Noctuidae) and sex ratio of the parasitoid *Cotesia marginiventris* (Hymenoptera: Braconidae). *Journal of Entomological Sciences* **36**: 188-198.

Wale, M., Schulthess,F., Kairu E.W. and Omwega,C.O. 2006. Cereal yield losses caused by lepidopterous stemborers at different nitrogen fertilizer rates in Ethiopia. *Journal of Applied Entomology* **130**: 220-229.

Zaidi, P.H. and Singh, N.N. 2005. Stresses on maize in tropics, Directorate of Maize Research, Pusa campus, New Delhi.