

**Screening of Chickpea Germplasm Against
Helicoverpa armigera (Hubner) and Estimation of
Losses Due to Insect Pests**

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MAMTA KUMARI MAHAWAR

Thesis

**Master of Science in Agriculture
(Entomology)**



2015

**DEPARTMENT OF ENTOMOLOGY
RAJASTHAN COLLEGE OF AGRICULTURE,
MAHARANA PRATAP UNIVERSITY OF AGRICULTURE AND TECHNOLOGY
UDAIPUR- 313001 (Raj.)**

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Thesis

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(Entomology)



By

MAMTA KUMARI MAHAWAR

2015

**Screening of chickpea germplasm against *Helicoverpa armigera*
(Hubner) and estimation of losses due to insect pests**

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ABSTRACT

The present investigation on, “*Screening of chickpea germplasm against Helicoverpa armigera (Hubner) and estimation of losses due to insect pests*” was carried out at the Instructional Farm, Rajasthan College of Agriculture, Udaipur during *rabi*, 2014-15. Common chickpea varieties of zone IV (a) were evaluated for their preference by the pod borer and the losses due to insect pests were estimated. Among the six varieties screened and expressed as per 4-m row, Pratap Chana was most preferred by the pod borer, as it harboured the maximum numbers of eggs (15.85), larvae (12.02) and damaged pods (41.44). The variety GNG 1581 was least preferred for egg laying (4.79); and had lowest larval population (3.80); RSG 888 had lowest numbers of damaged pods (4.19). On seed yield basis per 12 m² plot, variety RSG 902 had significantly more yield (2.96 kg) than GNG 1581 (1.75 kg) and RSG 888 (1.78 kg); however, Pratap Chana with a yield of 2.39 kg/plot was statistically at par with RSG 902 and was thus highly tolerant. The larval parasitoid, *C. chlorideae* was active from 15th December, 2014 to 26th January, 2015; but, the maximum parasitization varied on different varieties. The abundance of the parasitoid, *C. chlorideae* was significantly more on chickpea variety Pratap Chana, but effective parasitization was more on variety GNG 663. The relative parasitization was considerably less in different varieties as compared to that on Pratap Chana ranging from 30 to 54 per cent less. Correlation between pod borer and its parasitoid was significant (+ 0.83) for GNG 1581. The prevailing abiotic factors of the environment did not evince any significant effect on the pod borer and larval parasitoid population. The loss estimation due to insect pests on chickpea showed that plant stand was 30 per cent more when the crop was treated and kept pest-free; whereas, the mean larvae per plant was 6 times more and the mean number of damaged pods per plant were 7.7 times more when untreated. On the basis of yield, an avoidable loss of 26.57 per cent was recorded due to *H. armigera* infestation.

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INTRODUCTION

Chickpea (*Cicer arietinum* L.), also known as Bengal gram, gram or *chana* is an important *rabi* pulse crop of India and has been considered as ‘King of Pulses’ (Bhatt and Patel, 2001); consumed as a major nutrient supplement of protein. Globally chickpea is grown in over 45 countries and India occupies 80 per cent of world’s chickpea area (10.6 m. ha). The current productivity level in India is 872 kg/ha, which is far lower than its potential (up to 4 t/ha) realized at research stations, demonstration plots and on-farm trials (Gowda *et al.*, 2005). In Rajasthan chickpea is cultivated in an area of 14.34 lakh hectares with a production of 99 thousand tons and a productivity of 690 kg/ha (Anonymous, 2012). Chickpea productivity has not witnessed any significant jump as compared to cereals because of several biotic and abiotic constraints. Among the many biotic factors responsible for low yields, damage due to insect pests is a major limiting factor (Bhagwat *et al.*, 1995).

Bengal gram is infested by 57 species of insect pests and other arthropods in India; however, the major insect pest of chickpea is the gram pod borer, *Helicoverpa armigera* (Hubner), which is a polyphagous, multivoltine and cosmopolitan pest, known to feed on 182 species of plants belonging to 47 families in India (Sithanantham, 1987 and Panwar, 1998). *Helicoverpa armigera* has a wide host range, and feeds on more than 250 crop species (Kranthi *et al.*, 2002). High polyphagy, mobility, reproductive rate and diapause are major factors contributing to its serious pest status (Fitt, 1989 and Sharma *et al.*, 2005). The gram pod borer begins infestation at the seedling stage and later feeds on the flowers and developing seeds in pods until crop maturity (Reed *et al.*, 1987). The yield loss range in chickpea has been estimated to be from 10 to 60 per cent under normal weather conditions (Vaishmpayam and Veda, 1980); 50 to 100 per cent under favourable weather conditions with frequent cloudy days during the crop season that often accounts for about 90 to 95 per cent of the total damage caused by insect pests (Sachan and Katti, 1994).

Over 250 natural enemies have been recorded on *H. armigera* (Romeis and Shanower, 1996), of which, the egg parasitoids, *Trichogramma* spp. and the larval parasitoids, *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae), *Carcelia*

illota Curran, *Palexotista* spp., and *Goniozus* spp. are predominant parasitoids of *H. armigera* in different agro-ecosystems. However, the activity and abundance of natural enemies varies across crops (Pawar *et al.*, 1986), and different genotypes of the same crop (Romeis and Shanower, 1996; Sharma *et al.*, 2003; Dhillon and Sharma, 2007). Host plant selection by the female parasitoids, involves a series of complex responses in a non-random manner to a hierarchy of physical and/or chemical stimuli that lead them to their potential hosts (Vet and Groenewold, 1990; Lewis *et al.*, 1991; Tumlinson *et al.*, 1993). Parasitoids also respond to the volatiles emanating from both undamaged (McAuslane *et al.*, 1990; Li *et al.*, 1992; Turlings and Tumlinson, 1992; Udayagiri and Jones, 1992) and damaged (Whitman, 1988; Turlings *et al.*, 1990, 1995; Mattiacci *et al.*, 1994; de Moraes *et al.*, 1998; War *et al.*, 2011) plants. Genotypic resistance has a considerable influence on parasitism of insect pests in different crops. The nature of influence depends on the insect pest, natural enemy, and the crop (Sharma *et al.*, 2003). In chickpea, parasitization of *H. armigera* larvae by *C. chloridae* ranged from 8.33 to 28.00 per cent (Gupta and Raj, 2003), and varied considerably across genotypes (Kaur *et al.*, 2004). However, there is no information on genotypic effects on the activity and abundance of natural enemies in chickpea.

The gram pod borer has developed substantial resistance to pesticides (Challaiah, 1988); especially, very high levels of resistance to conventional insecticides, including synthetic pyrethroids (Kranthi *et al.*, 2002); therefore, developing chickpea cultivars having resistance to the pest is an important component of pest management strategy. Besides, a proper understanding of the tri-trophic relationship among the plant host, insect herbivore and the natural enemy complex, including the larval and pupal parasitoids, Ha-NPV and predators, becomes even more necessary; therefore, cultivation practices that enable conservation of the natural enemies of the pod borer should be followed and encouraged. The more common bio-intensive management practices include: installation of pheromone traps to collect the male moths, intercropping chickpea with coriander to enhance the activities of larval and pupal parasitoids of the pod borer, installation of bird perches to enable predation of *H. armigera* larvae by birds and timely application of Ha-NPV.

The present study was undertaken with the objectives to evaluate a few recommended varieties for preference by *H. armigera*, record the effect on the natural parasitization of *H. armigera* larvae by *C. chloridae* to identify genotypes that are compatible with the natural enemies of this pest and estimate the avoidable losses to chickpea due to this pest.

2. REVIEW OF LITERATURE

Chickpea being an important *rabi* season pulse crop has significant documentation for the major insect pests and their associated natural enemies; however, in the context of climate change and due to the anthropological influences, information on insect pest records and their management needs to be updated from time to time. With a view to achieve that, available literature has been reviewed as per the objectives of the research work.

2.1 Screening of chickpea genotypes for resistance to chickpea pod borer

Host plant resistance to a key insect pest is often the first step towards integrated pest management and many references are available. Ujagir (2005) reported four chickpea genotypes ('ICCV 93929', 'ICCV 96029', 'ICCV 96030' and 'ICCV 2') to have resistance to gram pod-borer with a pest damage score of 3 on a scale of 1-9. On the other hand, 'ICCV 10', 'ICCV 97115', 'ICCV 97119' and 'ICC 16381' proved tolerant, as they could gain greater seed yield than the others. Evaluating 20 genotypes, Gowda and Sharanabasappa Halle (2005) observed that BGD-237 recorded significantly the lowest pod damage (11.86 and 10.84% during 2000-01 and 2001-02, respectively). Of the 119 promising chickpea genotypes screened for resistance to *H. armigera*, the lowest mean incidence of pod borer on the promising genotypes, IC 269317, IC 268855, IC 269218 and IC 269347 ranged from 11.24 to 14.23% and the mean Pest Resistance Rating (PRR) was 3 on the promising genotypes (Cheema *et al.*, 2010). Deshmukh *et al* (2010) reported chickpea genotypes BG-372, HC-1, SAKI-9516, Vijay and Avrodhi to be comparatively less susceptible as they harboured lower larval population (1.07 to 1.32 larvae/ plant) and had lower damage to pods (11.41 to 14.16%). Sandhya and Chandekar (2010) observed chickpea variety BG-1069 to give the highest yield and least damage. Chandra *et al* (2013) evaluated 10 chickpea cultivars against pod borer in hyper arid partial irrigated western plain zone of Rajasthan and observed that no cultivar showed complete resistance; however, the mean larval population was lowest (<4.75 larvae/5 plants) on RSG-931 and GNG-1488, which were categorized as the least susceptible.

Out of the 24 genotypes screened against *H. armigera*, ICC 506 (resistant control) and A1 (local control), BG-1039, P-1772 B, L-550 and 86019 had minimum

ova load and were at par with ICC-506 and superior to A1, which recorded 2.70 ova per plant. Genotypes P-1772B recorded lowest larvae per plant (1.16), which was at par with Phule-G-95412 (1.32) and BGD-103 (1.38). The genotypes Phule G-92028, P-1772 B and BG-1039 emerged as the resistant genotypes (Ramegowda *et al.*, 2007). Kumar *et al* (2013) evaluated the performance of 100 chickpea genotypes against *Helicoverpa armigera* for yield and yield attributing characters and observed that pod damage and yield losses varied from 6.50 to 35.50 per cent and 410 to 1175 kg/ha, respectively. On the basis of pod damage, genotype BGD-115 (6.50%) was defined as least preferred by *H. armigera*, followed by ICC-1032 (7.25%); however, in spite of high pod damage minimum yield loss was recorded for BG-93009.

2.2 Population dynamics of the gram pod borer and its natural enemies

The extent of natural parasitization of *Helicoverpa armigera* (Hubner) by *Campoletis chloridae* on chickpea varied between 12.69 and 56.28 per cent during 1995-96 and 3.57 and 80.64 per cent during 1996-97 on a standard weekly basis. Parasitization recorded during 1995-96 was 37.17, 46.10, 42.67, 16.16, and 26.19 per cent during November, December, January, February, and March, respectively; while, the corresponding figures during 1996-97 were 51.04, 65.14, 63.39, 21.46 and 5.85 per cent, respectively (Sachan and Bhaumik, 1998). Gupta *et al* (1999) observed that when one row of coriander was intercropped with chickpea, there was significantly high parasitoid (6.4 cocoons/5 m row) and low pest activity (2.6 larvae/5 m row) resulting in minimum pod damage (9.6%) and highest seed yield (16.0 q/ha) compared to chickpea sole crops.

In a study on the role played by the larval parasitoid of *H. armigera* infesting gram, Kaur *et al* (2000) reported that parasitism due to *C. chloridae* ranged from 0.98 to 68.50 per cent throughout the crop season, while the maximum parasitism was recorded during the third week of February, 1999 when the minimum mean temperature was 11.9°C and relative humidity was 95 per cent. Devi *et al* (2002) recorded 5 different parasitoids associated with gram pod borer, *H. armigera*; of these, *Campoletis chloridae* Uchida was recorded as the most important natural enemy of this pest with parasitism ranging from 0.18 to 23.81 per cent from March to May. The maximum incidence of the parasitoids was recorded during the first and second week of April, 1998-2000 and a high positive relation between the pest and the parasitoid was recorded. Gupta and Desh Raj (2003) observed that *H. armigera*

larvae on chickpea were parasitized by *Apanteles* sp., *Diadegema fenestrale* and *Campoletis chlorideae* during two consecutive years 1997-98 and 1998-99. Among these, parasitization by the former two parasitoids remained negligible; however, the extent of parasitism by *C. chlorideae* ranged from 8.33 to 28.00 per cent. The parasitoid remained active from the second week of April to the first week of May, the activity of the parasitoid ceased when the mean maximum temperature reached above 40 °C and a significant positive correlation with total rainfall was observed. Multiple regression analysis revealed the significant effect of relative humidity and total rainfall on larval parasitism, both individually as well as in association with other abiotic factors to the extent of 74.15 per cent. The extent of natural larval parasitization by *C. chlorideae* on *H. armigera* varied from 5 to 41 per cent during 1999-2000 and 3 to 40 per cent during 2000-2001 on a standard week basis. Parasitization recorded during 1999-2000 was 33, 37.3, and 9 per cent during February, March and April, respectively; while, during 2000-2001 it was 36 and 5 per cent in March and April, respectively (Rai *et al.*, 2003).

Kaur *et al* (2004) reported a variation in the natural parasitization of *H. armigera* by the parasitoid, *C. chlorideae* on different chickpea cultivars. The parasitoid population varied from 0.02-1.50 cocoons per metre row length and the larval population ranged between 0.86 and 14.50 larvae per metre row length. The highest number of cocoons were recorded on PBG 5 (0.88) followed by L 550 (0.74). The *H. armigera* population was also high on PBG 5 (9.38 larvae/m row length) followed by L 550 (6.75 larvae/m row length). Chandel *et al* (2005) studied the population dynamics of *Helicoverpa armigera* (Hubner) on different crops, chickpea (cv. C-235), pigeon pea (cv. UPAS-120), tomato (cv. Pusa Ruby), sunflower and okra (cv. Pusa A-4) and observed the larval parasitoid, *Campoletis chlorideae* Uchida to be a key mortality factor. Pandey *et al* (2005) observed that chickpea crop sown before October 20 escaped pod borer infestation; while, parasitic activity of *C. chlorideae* was highest (80.5%) when maximum and minimum temperatures were 24.5 °C and 8.6 °C, respectively and relative humidity 85 per cent. The activity was the lowest (22.2%) when the above parameters were 36.6 °C, 18.5 °C and 85 per cent, respectively. Singh and Ali (2006) recorded the larval activity of *H. armigera* on chickpea throughout the crop season with two peaks, the first from 45th to 49th standard weeks and the second from 5th to 13th standard weeks. The maximum mean

larval populations of 6.3 and 6.4 larvae/ m² were observed in 45 and 12 standard weeks, respectively. Minimum and maximum temperatures showed a positive correlation with both larval and adult populations of *H. armigera*, while relative humidity showed a negative correlation. Singh and Ali (2006) reported maximum parasitization of *H. armigera* by *C. chloridae* in the IV standard week. Parasitization declined from 44th to 50th standard weeks. Minimum and maximum temperatures showed a negative correlation with parasitization, while relative humidity depicted a positive correlation. A survey conducted in chickpea fields during 15 November to 5 December, 2005 revealed that natural parasitism of gram pod borer, *Helicoverpa armigera* (Hubner) by the parasitoid, *Campoletis chloridae* ranged from 25.0 to 59.2 per cent, preferring the late instar or early second instar host larvae for parasitization (Kirti Pandey and Prabhat Kumar, 2006).

Among the larval and pupal parasitoids of gram pod borer, *Helicoverpa armigera* (Hubner), the ichneumonid, *Eriborus argenteopilosus* was active from 50th SMW (10-16 December) until 3rd SMW (15-21 January) and the maximum parasitization of early instar larvae was in 52nd SMW (22.50%). The other ichneumonid, *Campoletis chloridae* Uchida was observed from 51st SMW (17-23 December) until 3rd SMW (15-21 January) and caused 8.11 to 11.54 per cent parasitization. *E. argenteopilosus* was the dominant parasitoid and contributed almost half of the total mortality. A tachinid fly was observed to parasitize the late instar larvae and pupae of *H. armigera* (Bisane *et al.*, 2008). Pandey and Ujagir (2009) studied the effect of intercropping coriander, linseed and barley in chickpea on the activity of the larval parasitoid, *Campoletis chloridae* Uchida on the chickpea pod borer, *Helicoverpa armigera* (Hubner) and observed that at flowering and early pod stage of the crop, there was higher parasitization by *C. chloridae* compared with crop reaching maturity. The mean larval parasitization was the maximum (30.16%) in chickpea + coriander (4:1), while minimum (15.73 & 19.27%) in chickpea + barley (6:1) in comparison to 15.98 per cent in chickpea sole crop during 2003-04; whereas, during 2004-05, the mean larval parasitization was maximum (50.50%) in chickpea + coriander (2:1), while minimum (19.27%) in chickpea + barley (6:1). Pooled data of both the years showed that maximum larval parasitization (39.86%) was recorded in chickpea + coriander (2:1), while minimum (17.50%) in chickpea + barley (6:1) as compared to 19.50 per cent in chickpea sole crop. Life table studies by Bisane *et al*

(2009) indicated that among early instar larvae, 34.55 per cent mortality was noticed, in which highest parasitization (14.89%) was due to *Eriborus argenteopilosus* Cameron and 8.94 per cent due to *Campoletis chlorideae* Uchida. Among the late instar and pre-pupal larvae, tachinid fly activity was highest that recorded 3.73 and 6.31 per cent parasitism, respectively. Moreover, HaNPV disease infection of 0.60 and 0.41 per cent was observed in early and late instar larvae, respectively. Pupal stage was the most vulnerable stage than other stages and showed 35.16 per cent population suppression, in which the tachinid fly recorded the maximum (13.19%) parasitization.

Chatar *et al* (2010) recorded the chickpea pod borer infestation to begin from 2nd week of December that attained a peak of 3.12 larvae per plant during 2nd week of January. The pest was active during the last week of December to 3rd week of January. Later on, the pest population declined gradually towards the maturity of the crop. Correlation of *H. armigera* with different weather parameters indicated that maximum temperature exhibited highly significant negative correlation ($r=-0.7514$) with larval population of *H. armigera*, whereas, minimum temperature ($r=-0.5771$) and mean temperature ($r=-0.6836$) exhibited significant negative correlation. However, the pest population showed highly significant positive correlation with morning relative humidity ($r=0.7098$), evening relative humidity ($r=0.7293$) and mean relative humidity ($r=0.8063$). Agnihotri *et al* (2011) recorded the peak period of activity of the pod borer parasitoid, *C. chloridae* during 6th standard week parasitizing 89.56 and 90.93 per cent larval population of *H. armigera*, in 2008-09 and 2009-10, respectively. The per cent parasitization showed a negative correlation with mean temperature, sunshine hours and wind velocity; whereas, a significant positive correlation with relative humidity. Munni Lal *et al* (2013) observed two peaks of the larval population of gram pod borer; the first during 49th standard meteorological week (SMW) with a maximum of 1.73 and 2.13 larvae per metre-row length and second with 8.93 and 7.93 larvae per metre-row during 8-9th SMW in 2003-04 and 2004-05, respectively. The ichneumonid parasitoid, *Campoletis chlorideae* Uchida exhibited reciprocal relationship with environmental parameters and suppressed the larval population of *H. armigera*. Kumar and Bisht (2013) observed gram pod borer infestation in chickpea to begin from the second fortnight of December, reaching the peak in the first week of April during 2009-10 and in the last week of March during

2010-11. The larval population of the pest occurred throughout the growth period of the crop and was the maximum at pod and grain formation stages. Maximum and minimum temperatures, sunshine hours and wind speed showed significant positive correlation with larval population, whereas relative humidity and rainfall exhibited negative impact on larval population. Ramteke *et al* (2014) reported that *H. armigera* infestation began in the IV-Standard Meteorological Week (0.34 larva/ plant), increasing gradually and reaching to the peak (9.97 larvae/ plant) in the X-Standard Meteorological Week (2nd Week of March). The pod borer population exhibited a significant positive correlation with maximum and minimum temperatures. The larval population increased suddenly with temperature rising from 28.61 to 32.44 °C; while decreased with increase in temperature from 32.64 and 38.04 °C.

2.3 Estimation of losses in chickpea due to gram pod borer infestation

Srivastava and Srivastava (1990) observed the mean pod damage to chickpea (*Cicer arietinum*) by *Helicoverpa armigera* in protected and unprotected plots as 0.9 and 5.9 per cent, respectively during 1984; while, 1.0 and 6.4 per cent, respectively during 1985. The loss in grain yield in the unprotected plot compared to the protected plot was 115 kg/ha (avoidable loss = 16.7%) in 1984 and 128 kg/ha (avoidable loss = 18%) in 1985. Biradar *et al* (1998) reported that five spray applications of methomyl 12.5 SL (2ml/litre of water) during the vegetative and reproductive stages of crop growth in chickpea caused lowest pod borer incidence (18.7%) with the maximum yield (11.5q/ha) thus avoiding a loss up to 55.7 per cent, while three applications during the reproductive stage had 21.5 per cent pod damage, 9.5 q/ha seed yield thus avoiding the loss up to 46.3 per cent. Mehta *et al* (2000) recorded yield losses due to the pod borer in two cultivars of chickpea to be 23.35 per cent (cv. C-235) and 20.08 per cent (cv. HPG-17) during 1996-98. Chaturvedi (2004) observed maximum damage during the reproductive phase of the crop with a damage of 36.4 per cent to the pods by *Helicoverpa armigera* (Hubner); the pod borer population was lowest (1-2 larvae/m-row) in crop protected till harvest by applying insecticides from flowering at 15 days intervals, while the highest (8-10 larvae/m-row) was recorded from the untreated crop. The mean damage by semilooper, *Autographa nigrisigna* was 15.72 per cent in the untreated crop and 3.75 per cent in crop protected till harvest. Singh *et al* (2008) reported yield loss in chickpea due to *H. armigera* to vary from 36.88 to 50 per cent in different localities of Uttar Pradesh (India). Deshmukh *et al* (2010) opine

that chickpea when protected against pod borer, *H. armigera* through application of quinalphos (0.05%) and indoxacarb (0.0075%) alternatively at an interval of 10 days starting from 50 per cent flowering stage till maturity of the crop resulted in avoiding grain yield loss of 41.17 per cent.

3. MATERIALS AND METHODS

The present investigation entitled, “Screening of chickpea germplasm against *Helicoverpa armigera* (Hubner) and estimation of losses due to insect pests” was carried out during *rabi* 2014-15 at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. The details of materials used and the methodology adopted have been mentioned below:

3.1 Location of the experimental site:

The field experiment was conducted at the Instructional Farm, Rajasthan College of Agriculture, Udaipur. Geographically Udaipur is situated at 75.4⁰ E Latitude and 23.4⁰ N Longitude at an elevation of 582.17 MSL in the sub-humid Southern region of Rajasthan.

3.2 Climatic conditions of the location:

The zone has a typical sub-tropical climatic condition characterized by moderate winter and hot summer associated with high humidity especially during months of July to September. The average rainfall of this tract ranges between 450-650mm, which is contributed by South-West monsoon from July to September with occasional rains during the winter season. During summers, the atmospheric temperature may go as high as 45.5⁰C, while in winters, it may fall as low as 3.5⁰C occasionally.

3.3 Field preparation and sowing of chickpea crop:

After the harvest of *kharif* crops, the experimental field allotted was prepared by deep ploughing once and cross harrowing twice to improve the field conditions.

- a) Under the objective of field screening of chickpea varieties for their preference by the pod borer, *H. armigera*, six varieties of chickpea recommended for Rajasthan were evaluated. The varieties Pratap chana, RSG-902, GNG-469, GNG-663, GNG-1581, RSG-888 were sown on 4th November, 2014.
- b) With a view to estimate the losses another experiment was laid out in which chickpea variety, Vijay was sown on 4th November, 2014. All recommended agronomic practices including hoeing, weeding and

irrigation were performed as and when needed following the package of practices for cultivation of chickpea.

3.4 Experimental Details:

a) Screening of chickpea varieties

Six varieties recommended for the zone Pratap chana, RSG-902, GNG-469, GNG-663, GNG-1581, RSG-888 were evaluated for their preference by the gram pod borer. The experiment was laid out as detailed below:

Design	-	RBD
Replications	-	04
Treatments	-	6 (varieties: as mentioned above)
Plot size	-	4m x 3m
Spacing	-	30cm x 10cm
Main Crop	-	Chickpea

The relative parasitization effect (%) and effective parasitization (%) were computed using the methodology adopted by Hugar *et al* (2014) and Tian *et al* (2008).

No effect on parasitization = No difference in relative parasitization between the test genotype and the susceptible check, ICPL 87.

Negative effect on parasitization = Parasitization of the *H. armigera* larvae on the test genotype is significantly lower than on the susceptible check, ICPL 87.

Positive effect on parasitization = Parasitization of *H. armigera* larvae on the test genotype is significantly greater than on the susceptible check, ICPL 87.

Relative Parasitization (%) =

$$\frac{\text{No of larvae parasitized on test genotype} - \text{No of larvae parasitized on susceptible check}}{\text{No of larvae parasitized on test genotype} + \text{No of larvae parasitized on susceptible check}} \times 100$$

Effective Parasitization (%) =

$$\frac{\text{Number of larvae parasitized}}{\text{Number of larvae effectively parasitized} + \text{No of healthy larvae}} \times 100$$

b) Estimation of losses in chickpea due to pod borer (*H. armigera*)

The loss estimation trial was laid out in Randomized Block Design as per model of Leclerg (1971) at the Instructional Farm, RCA, Udaipur, as per details given below:

Design	-	RBD
Replications	-	13
Treatments	-	2 (Treated/ Untreated)
Plot size	-	4m x 3m

Spacing	-	30cm x 10cm
Main Crop	-	Chickpea, variety Vijay

The treated plots were kept free from insect infestation for which seed treatment with thiamethoxam 30 FS was done followed by weekly spray of recommended doses of insecticides alternating quinalphos (0.05%) with deltamethrin (0.005%) and cypermethrin (0.01%) beginning from 30 days after germination; whereas, the untreated plots were left free for pod borer infestation. To estimate the losses caused by the pod borer the following parameters were recorded in both the treatments: Numbers of plants per plot; Numbers of pods per plant; Yield per plant (g) Yield per plot (g):

$$\text{Loss in yield (\%)} = \frac{X_1 - X_2}{X_1} \times 100$$

Where, X_1 = Yield in treated plot

X_2 = Yield in untreated plot

The yield data was subjected to statistical analysis and significance tested by "t" test:

$$t = \frac{Y_1 - Y_2}{\text{S. Ed.}}$$

Where

Y_1 = Average yield in treated plot

Y_2 = Average yield in untreated plot

S. Ed. = Standard error of difference of mean

$$\text{Standard deviation (s)} = \frac{\text{S S of the deviation from the mean difference}}{\text{Number of paired plots} - 1}$$

$$\text{Standard error of mean difference (S. Ed.)} = \frac{\text{Standard deviation (s)}}{\text{Number of paired plots (n)}}$$

3.5 Observations recorded in both experiments mentioned above:

(a) Greasy cutworm:

An estimate of the number of plants damaged per plot/ replicate was done, but there was no incidence of the cutworm during the season.

(b) Gram pod borer:

- Observations on the numbers of eggs per plant from randomly selected plants in three 4m-rows were taken for each variety replicate-wise in the varietal screening trial. Observation for preference of egg laying by *H. armigera* on the different gram varieties was recorded from 5 plants selected at random and tagged in each replicate.
- Record of the total numbers of plants with egg laying per replicate for each variety screened was made and expressed as a percentage of plants harbouring *H. armigera* eggs in the different varieties for comparison.
- During early hours of the day (7 to 9 am) observations for *Helicoverpa armigera* larvae infesting the crop were taken along the 4-metre-row, selecting 3 rows from each plot/ replicate for each variety replicate-wise in the varietal screening trial; and from both treated/ untreated plots in the loss estimation trial during vegetative stage of crop growth. Later, after pod initiation, the total numbers of pods, numbers of damaged pods per plant were counted.

(c) Larval parasitoid:

- From the same rows observed for the pest, the numbers of parasitized larvae were field collected and brought to the laboratory for the parasitoid adult emergence in the varietal screening and loss estimation trials. Particular care was taken to record the influence of variety on parasitoid abundance and efficacy. The field-collected parasitized larvae were brought to the laboratory and maintained in glass jars of 500ml capacity that were covered with muslin cloth fastening the cloth with rubber bands until adult parasitoid emergence.
- Photographs of the pest and its parasitoid in the field were taken. For morphological characterization of the parasitoid, photographs of significant taxonomical characters were taken under the stereozoom binoculars Stemi 2000 C of Carl Zeiss make. Necessary line drawings of taxonomical importance were drawn with the help of a drawing tube under

the stereozoom binoculars Nikon SMZ 1500. The line drawing of the wings was made at 7x magnification for clarity.

- The parasitoids collected were identified using standard references and internet sources (NBAIR, Bangalore). The entire collection of 362 parasitoids happened to be males and females of *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae).

4. RESULTS

Investigations on screening of chickpea germplasm against the pod borer, *Helicoverpa armigera* (Hubner) Harwickii and estimation of losses in chickpea due to insect pests were carried out at the Instructional Farm and Department of Entomology of Rajasthan College of Agriculture, MPUAT, Udaipur, during *rabi* 2014-15. The results of the experiments taken have been presented objective-wise in this Chapter:

4.1 Chickpea germplasm screening for preference/ non-preference by *H. armigera*:

From among the common recommended varieties for the Zone IV (a), six varieties *viz.*, Pratap Chana, RSG 902, GNG 469, GNG 663, GNG 1581, and RSG 888 were evaluated for their preference by the pod borer, *H. armigera* and their influence on the natural parasitization of the pod borer larvae by the Icneumonid parasitoid, *Camponotus chlorideae* Uchida was studied.

From Table (1) and Figure (1) it can be observed that variety Pratap Chana was the most preferred variety of the pod borer as, on this variety, significantly the maximum mean numbers of eggs were laid (15.85 eggs per 4-m row), the maximum mean numbers of larvae were recorded (12.02 caterpillars per 4-m row) and the maximum damage to pods was also observed (41.44 pods per 4-m row). On the other hand, variety GNG 1581 happened to be the least preferred variety as it harboured significantly the lowest numbers of eggs (4.79 eggs per 4-m row), least numbers of larvae (3.80 caterpillars per 4-m row) and also lower numbers of damaged pods (5.74 pods per 4-m row). However, variety GNG 663 also harboured the lesser numbers of larvae (3.89 caterpillars per 4-m row) and variety RSG 888 had the lowest numbers of damaged pods (4.19 pods per 4-m row). When the yield parameters obtained from 12m² plots were compared, the lowest yield was recorded for variety GNG 1581 (1.75 kg/plot), though it was least preferred by the pod borer, being at par with that of Pratap Chana, GNG 469, GNG 663 and RSG 888. The variety RSG 902 significantly yielded the maximum (2.96 kg/plot). Based on the yield attributes the varieties RSG 902, GNG 663, Pratap chana and GNG 469 were tolerant to the pod borer infestation and yielded relatively more than varieties GNG 1581 and RSG 888.

4.2 Influence of variety on quantitative abundance of *H. armigera* infesting chickpea and the associated larval parasitoid:

The natural parasitization of *H. armigera* by the Ichneumonid parasitoid, *C. chloridae* (Table: 2 and Figure: 2) indicates that parasitization was significantly more on varieties GNG 663 (34.84 %), GNG 469 (33.16 %) and RSG 902 (30.27%); however, the numerical abundance of the parasitoid was significantly more on the variety Pratap Chana in terms of numbers (10.47) and mean parasite count (17.93). On the different varieties, the mean numbers of caterpillars in a 4-m row ranged from 3.80 (GNG 663) to 12.02 (Pratap Chana); the observed parasitoid abundance ranged from 2.74 (GNG 1581) to 10.47 (Pratap Chana); per cent parasitization ranged from 24.74 (RSG 888) to 34.84 (GNG 663); and the mean parasite count ranged from 4.43 (GNG 1581) to 17.93 (Pratap Chana). The overall assessment indicates that Pratap Chana was most preferred by the pod borer as well as the associated parasitoid was also the maximum on this variety; while, the variety GNG 1581 was among least preferred by the pod borer, but was also least visited by the parasitoid, defining the density-dependent activity of the parasitoid.

The relative parasitization by the Ichneumonid parasitoid on different varieties in comparison to that on Pratap Chana (Table 3) clearly indicated that more than 50 per cent less parasitization occurred on varieties GNG 1581 (-54.10), RSG 888 (-53.36) and GNG 663 (-52.19); while, parasitization was 38.97 and 30.20 per cent less on varieties RSG 902 and GNG 469, respectively. From the Table (4) it is conspicuous that the effective parasitization, as per method suggested by Tian *et al* (2008), was the maximum on variety GNG 469 (65.15 %), followed by that on Pratap Chana (61.40 %), while the minimum on RSG 888 (44.10 %).

The seasonal parasitization trend as given in Table (5) shows that irrespective of the gram variety, natural field parasitization was noted from 15th December, 2014 onwards that gradually increased in the subsequent weeks with a significant variation continuing up to the last week of January, 2015. The per cent parasitization in the different varieties evaluated ranged from 18.97 to 32.63 (Pratap Chana); 20.30 to 46.40 (RSG 902); 20.70 to 41.44 (GNG 469); 26.44 to 45.90 (GNG 663); 21.03 to 33.33 (GNG 1581) and 12.86 to 29.28 (RSG 888).

The abiotic factors of the environment did not seem to significantly affect the effective per cent parasitization of *H. armigera* by *C. chloridae*; however, the atmospheric temperature had a variable response among the chickpea varieties; relative humidity was uniformly positively correlated to parasitization across the varieties and sunshine showed a negative correlation with parasitization for all the varieties evaluated (Table: 4). Whereas, the observed numerical abundance of the larval parasitoid of the pod borer showed significant negative correlation with the mean atmospheric temperature only on chickpea variety RSG 902 ($r = -0.78^*$); while, on other varieties the correlation coefficients for different factors of the environment had no significant relationship. Likewise, the population of *H. armigera* had a negative correlation with the mean relative humidity that was significant only on chickpea variety GNG 663 ($r = -0.71^*$). The relationship between pod borer and its parasitoid evinced either a positive or negative non-significant correlation for five of the six varieties; however, the correlation coefficient ($r = 0.83^*$) was positive and significant only on the chickpea variety GNG 1581 (Table: 6).

Morphological characterization of the larval parasitoid, *C. chloridae* has been detailed out in the Plate: I, as depicted by the line drawings of the morphological identification traits.

4.3 Estimation of losses due to the gram pod borer:

The population dynamics of gram pod borer, *H. armigera* on chickpea variety Vijay, in the untreated plots of the loss estimation trial, as presented in Table (7), shows that the larval numbers were significant from early December, 2014 (6.28 per 4-m row) that increased gradually reaching the peak on 15th December, 2014 (10.51 per 4-m row) and with a seasonal mean of 5.81 larvae per 4-m row. Among the prevailing abiotic factors of the environment, only the mean relative humidity showed a significant negative correlation with the pod borer larval population ($r = -0.64^*$). The pod borer larvae were parasitized in nature by the parasitoid, *C. chloridae* from 22nd December, 2014 with 3.53 per cent parasitisation that increased to a maximum of 12.35 per cent the next week on 29th December, 2014; however, the parasite happened to be active from IV week of December, 2014 to the II week of January, 2015.

The loss estimation due to infestation of chickpea by *H. armigera* taking into account different parameters of crop growth and the yield attributing traits (Table: 8) indicates that the mean plant stand per plot and the mean number of pods per plant

were significantly less in the untreated plots than in those treated. The plant stand under treated conditions was 1.43 times more than under untreated conditions; likewise, the mean numbers of pods per plant were 1.2 times more. The numbers of pod borer larvae (52.24 per 4-m row) and quantum of damaged pods (22.69 pods per 4-m row) were significantly more in the untreated plots, being 6.4 and 7.69 times higher; ultimately, the resultant mean yield (2408.92 g/plot) was significantly more when the crop was kept treated with negligible infestation. The overall mean loss worked out to be 26.57 per cent due to the pod borer infestation alone as there were no other notable pestiferous insects on the crop; however, when the data was converted on a per hectare basis the loss was 29.10 per cent.

4.4 Morphological characterization of the major parasitoid of *H. armigera*

The larval parasitoid of *H. armigera* was identified as *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae) with the help of identification key provided by NBAIR, Bangalore (URL: www.nbair.res.in, 2013) and has been presented in Plate I. As per the key mentioned above, the important taxonomic features observed for the species include: areolet in forewing receiving second recurrent vein a little before middle and apical margin of clypeus with an obtuse median tooth.

5. DISCUSSION

In the light of available literature and similar work done on chickpea, the investigations on screening of chickpea germplasm against the pod borer, *Helicoverpa armigera* (Hubner) Harwickii and estimation of losses in chickpea due to insect pests carried out at the Instructional Farm and Department of Entomology of Rajasthan College of Agriculture, MPUAT, Udaipur, during *rabi* 2014-15, have been discussed hereunder:

5.1 Chickpea germplasm screening for preference/ non-preference by *H. armigera*:

Among the recommended chickpea varieties of the Zone evaluated for their preference to the pod borer, Pratap Chana was the most preferred as indicated by the maximum numbers of eggs laid, pod borer larvae during the crop season and the numbers of damaged pods. The variety GNG 1581 was the least preferred by *H. armigera* on account of bearing lowest numbers of eggs, lowest larval population and lesser pod borer damaged pods. On the basis of the varietal character for yield potential, Pratap Chana could tolerate the infestation and had relatively more yield than GNG 1581; however, the variety RSG 902 yielded significantly more than the varieties GNG 1581 and RSG 888; whereas, relatively yielded more than the varieties GNG 663, Pratap Chana and GNG 469, but being statistically at par.

From the literature it can be observed that laying of eggs by *H. armigera* on chickpea varied considerably among varieties. Of the 24 genotypes screened against *H. armigera*, ICC 506 (resistant control) and A1 (local control), BG-1039, P-1772 B, L-550 and 86019 had minimum ova load and were at par with ICC-506 and superior to A1, which recorded 2.70 ova per plant (Ramegowda *et al.*, 2007). Deshmukh *et al* (2010) reported chickpea genotypes BG-372, HC-1, SAKI-9516, Vijay and Avrodhi to be comparatively less susceptible as they harboured lower larval population (1.07 to 1.32 larvae/ plant) and had lower damage to pods (11.41 to 14.16%). Likewise, the mean larval population was lowest (<4.75 larvae/5 plants) on RSG-931 and GNG-1488, which were categorized as the least susceptible to the gram pod borer under hyper arid partial irrigated western plain zone of Rajasthan (Subhash Chandra *et al.*, 2013).

5.2 Influence of variety on quantitative abundance of chickpea pod borer and the associated larval parasitoid:

The natural parasitization of *H. armigera* by the Ichneumonid parasitoid, *C. chlorideae* was recorded across the varieties screened for pod borer preference/tolerance. The numerical abundance of the parasitoid was significantly more on the chickpea variety Pratap Chana, but effective parasitization was observed to be relatively more on variety GNG 663; whereas, the variety GNG 1581 was least preferred by the pod borer and also least visited by the parasitoid. The relationship between the herbivore host, *H. armigera* and its parasitoid, *C. chlorideae* was strictly density-dependent on all the chickpea varieties evaluated. The tritrophic relationship among the host plant variety, the herbivore pod borer and its larval parasitoid happened to have the best cascading effect on the variety Pratap Chana on account of the maximum larval population, observed parasitization abundance and the mean parasite count; however, the observed parasitization in terms of per cent parasitization was significantly more on the varieties GNG 663, followed by that on GNG 469 and RSG 902. Among the varieties evaluated, GNG 1581 was least preferred by the herbivore pod borer and also by the parasitoid, possibly due to low survival of *H. armigera* on this variety. The variety Pratap Chana relatively favours the occurrence of the larval parasitoid, *C. chlorideae* in comparison to the other varieties evaluated; hence, is more suitable for IPM programmes. This could be ascertained while comparing the relative parasitization among the varieties screened in relation to Pratap Chana and the relative parasitization for different varieties ranged from 30 to 54 per cent less than on Pratap Chana.

Earlier reports indicate that more than 250 natural enemies have been recorded on *H. armigera* (Romeis and Shanower, 1996), of which, the egg parasitoids, *Trichogramma* spp. and the larval parasitoids, *Campoletis chlorideae* Uchida (Hymenoptera: Ichneumonidae), *Carcelia illota* Curran, *Palexotista* spp., and *Goniozus* spp. are predominant parasitoids of *H. armigera* in different agro-ecosystems. It has also been observed that the activity and abundance of natural enemies varies across crops (Pawar *et al.*, 1986), and different genotypes of the same crop (Romeis and Shanower, 1996; Sharma *et al.*, 2003; Dhillon and Sharma, 2007). In chickpea, parasitism of *H. armigera* larvae by *C. chlorideae* ranged from 8.33 to 28.00% (Gupta and Raj 2003), and varied considerably across genotypes (Kaur *et al.*,

2004). However, there is no information on genotypic effects on the activity and abundance of natural enemies in pigeonpea.

Studies were undertaken to identify pigeonpea, *Cajanus cajan* (L.) Millspaugh, and the wild relative of pigeonpea, *Cajanus scarabaeoides* (L.) (accession ICPW 125,) genotypes that are hospitable to the pod borer, *Helicoverpa armigera* (Hübner) (Lepidoptera: Noctuidae) larval parasitoid, *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae) for the management of this pest in pigeonpea based cropping systems. Percentage parasitization of the *H. armigera* larvae by the *C. chloridae* females was greater under no-choice conditions than under multi-choice conditions because of forced parasitization under no-choice conditions. Lowest parasitization was recorded on the wild relative, ICPW 125, which may be due to long non-glandular hairs and low survival of *H. armigera* larvae. Parasitization of *H. armigera* larvae was greater under no-choice, dual-choice and/or multi-choice conditions on ICPL 87, ICPL 87119 and ICPL 87091, which are susceptible to *H. armigera*, than on the pod borer-resistant genotypes ICPL 332WR, ICPL 84060 and ICPB 2042; while survival and development of the parasitoid was better on *H. armigera* larvae fed on ICPL 87, ICPL 87119, LRG 41, ICP 7035 and ICPL 87091 than on ICPL 332WR, ICPL 84060, ICPB 2042 and ICPW 125. The genotypes ICPL 87, ICPL 87119, LRG 42 and ICPL 87091 that are hospitable to *C. chloridae*, are better suited for use in integrated pest management to minimize the losses due to *H. armigera* in pigeonpea (Hugar *et al.*, 2014).

5.3 Avoidable losses caused by the gram pod borer:

The population dynamics of gram pod borer, *H. armigera* on chickpea variety Vijay under untreated conditions revealed that the larval population was significant from early December, 2014 that increased gradually reaching the peak by mid-December. Among the prevailing abiotic factors of the environment, only the mean relative humidity showed a significant negative correlation with the pod borer larval population. The pod borer larvae were parasitized in nature by the parasitoid, *C. chloridae* from 22nd December, 2014 and the maximum parasitization occurred in the last week of December, which was a key density-dependent mortality factor.

The gram pod borer is usually active from October through March with wide variations for different locations and the associated larval and larval-pupal parasitoids,

which are density dependent and location specific, also abound during this period. Earlier, Sachan and Bhaumik (1998) observed that the extent of natural parasitization of *Helicoverpa armigera* (Hubner) by *Campoletis chlorideae* on chickpea varied between 12.69 and 56.28 per cent (1995-96) and 3.57 and 80.64 per cent (1996-97) on a standard weekly basis. Parasitization recorded during 1995-96 was 37.17, 46.10, 42.67, 16.16, and 26.19 per cent during November, December, January, February, and March, respectively; while, the corresponding figures during 1996-97 were 51.04, 65.14, 63.39, 21.46 and 5.85 per cent, respectively.

The parameters for avoidable loss estimation showed that the plant stand was 30 per cent more when the crop was the treated and kept pest free; the mean larvae per plant was 6 times more, and the mean numbers of damaged pods per plant were 7.7 times more when untreated. On the basis of yield an avoidable loss of 26.57 per cent was recorded. The available literature indicates that loss estimation varies widely and is location specific. Srivastava and Srivastava (1990) observed the mean pod damage to chickpea (*Cicer arietinum*) by *Helicoverpa armigera* in protected and unprotected plots as 0.9 and 5.9 per cent, respectively during 1984; while, 1.0 and 6.4 per cent, respectively during 1985. The loss in grain yield in the unprotected plot compared to the protected plot was 115 kg/ha (avoidable loss = 16.7%) in 1984 and 128 kg/ha (avoidable loss = 18%) in 1985. Mehta *et al* (2000) recorded yield losses due to the pod borer in two cultivars of chickpea to be 23.35 per cent (cv. C-235) and 20.08 per cent (cv. HPG-17) during 1996-98. Chaturvedi (2004) observed maximum damage during the reproductive phase of the crop with a damage of 36.4 per cent to the pods by *Helicoverpa armigera* (Hubner). Singh *et al* (2008) reported yield loss in chickpea due to *H. armigera* to vary from 36.88 to 50 per cent in different localities of Uttar Pradesh (India). Deshmukh *et al* (2010) opine that chickpea when protected against pod borer, *H. armigera* resulted in avoiding grain yield loss of 41.17 per cent.

6. SUMMARY

Investigations on screening of chickpea germplasm against the pod borer, *Helicoverpa armigera* (Hubner) and estimation of losses in chickpea due to insect pests were carried out at Instructional farm and Department of Entomology of Rajasthan College of Agriculture, MPUAT, Udaipur, during *rabi*, 2014-15.

Among the recommended chickpea varieties of the zone IV (a) evaluated for their preference by the pod borer, Pratap Chana was most preferred as indicated by maximum number of eggs laid, pod borer larvae during the crop season and the numbers of damaged pods. The variety GNG 1581 was the least preferred by *H. armigera* thereby bearing lowest number of eggs; variety GNG 663 had the lowest numbers of larvae and pod borer damage was lowest in variety RSG 888 though they were statistically at par with variety GNG 1581. On the basis yield, the variety RSG 902 yielded significantly more than the varieties GNG 1581 and RSG 888; and yielded relatively more than varieties GNG 663, Pratap Chana and GNG 469 being statistically at par. The overall screening showed that variety Pratap Chana despite having maximum numbers of eggs, larvae, together with maximum numbers of damaged pods yielded high at par with variety RSG 902 indicating it to be highly tolerant to pod borer infestation.

The natural parasitization of *H. armigera* by the Ichneumonid parasitoid, *C. chloridae* was recorded across the varieties screened for the pod borer preference/tolerance. The larval parasitoid, *C. chloridae* was active from 15th December, 2014 and continued up to 26th January, 2015, while the maximum parasitization varied on different varieties. The abundance of the parasitoid was significantly more on the chickpea variety Pratap Chana, but effective parasitization was more on variety GNG 663. The relative parasitization among the varieties screened was much less in relation to Pratap Chana and ranged from 30 to 54 per cent lesser than on Pratap Chana.

The abiotic factors of the environment, especially mean atmospheric temperature, relative humidity and sunshine did not seem to have a significant impact on the pod borer larval population as well as the parasitoid. However, the correlation between the pod borer larvae and its parasitoid, *C. chloridae* was highly significant and positive for the chickpea variety GNG 1581.

Loss estimation due to insect pests was worked out on chickpea variety Vijay. The larval population of gram pod borer, *H. armigera* under untreated conditions was significant from early December, 2014 that increased gradually reaching the peak by the mid- December. Among the prevailing abiotic factors of the environment, only the mean relative humidity showed a significant negative correlation with the pod borer larval population. The pod borer larval parasitoid, *C. chlorideae* was active from 22nd December, 2014 and the maximum parasitization occurred in the last week of December.

Of the different loss estimation parameters studied, the plant stand was 30 per cent more when the crop was treated and kept pest free. When the crop was maintained untreated allowing free pod borer infestation, the mean larvae per plant was 6 times more, and the mean number of damaged pods per plant were 7.7 times more than when treated. Resultantly, on the basis of yield, an avoidable loss of 26.57 per cent was recorded due to *H. armigera* infestation in chickpea variety Vijay.

LITERATURE CITED

- Agnihotri, M., Gairola, S.C. and Basera, A. 2011. Seasonal incidence of *Campoletis chlorideae* Uchida, a larval parasitoid of *Helicoverpa armigera* (Hubner) in chickpea. *Journal of Insect Science (Ludhiana)*, **24**: 362-366.
- Anonymous. 2012. Annual Report 2011-12, Department of Agriculture, Government of Rajasthan, Jaipur.
- Bhagwat, V.R., Aherkar, S.K., Satpute, U.S. and Thakare, H.S. 1995. Screening of chickpea (*Cicer arietinum* L.) genotypes for resistance to gram pod borer, *Helicoverpa armigera* (Hubner) and its relationship with malic acid in leaf exudates. *Journal of Entomological Research*, **19**: 249-253.
- Bhatt, N.J. and Patel, R.K. 2001. Screening of chickpea cultivars for their resistance to gram pod borer, *Helicoverpa armigera*. *Indian Journal of Entomology*, **63**: 277- 280.
- Biradar, A.P., Balikai, R.A. and Teggelli, R.G. 1998. Loss estimation and development of spray schedule in bengal gram due to pod borer. *Karnataka Journal of Agricultural Sciences*, **11**: 662-664.
- Bisane, K.D., Khande, D.M., Bhamare, V.K. and Katole, S.R. 2009. Life Table Studies of *Helicoverpa armigera* (Hubner) on Chickpea. *International Journal of Plant Protection*, **2**: 54-58.
- Bisane, K.D., Nehare, S.K. and Khande, D.M. 2008. Extent of parasitization of *Helicoverpa armigera* (Hubner) by larval and pupal parasitoids on chickpea. *Journal of Entomological Research*, **32**: 295-301.
- Challaiah, S. 1988. Changes in insect population due to pesticide application. Paper presented at National Seminar on, “*Changing Pest in the Current Agricultural Scenario of India*” 14-16 June, 1988. Indian Agriculture Research Institute, New Delhi, India.
- Chandel, S.F., Singh, P.K. and Ahmad, R. 2005. Population dynamics of *Helicoverpa armigera* (Hubner) and *Campoletis chlorideae* on different crops. *Annals of Plant Protection Sciences*, **13**: 379-383.

- Chandra, S., Nanda, V.S. and U.S. 2013. Varietal screening of chickpea against pod borer in hyper arid partial irrigated western plain zone of Rajasthan. *Indian Journal of Entomology*, **75**: 175-177.
- Chatar, V.P., Raghvani, K.L., Joshi, M.D., Ghadge, S.M., Deshmukh, S.G. and Dalave, S.K. 2010. Population dynamics of pod borer, *Helicoverpa armigera* (Hubner) infesting chickpea. *International Journal of Plant Protection*, **3**: 65-67.
- Chaturvedi, I. 2004. Extent of losses due to insect pests infesting *Cicer arietinum* L. in Chhattisgarh. *Plant Protection Bulletin (Faridabad)*, **56**: 20-21.
- Cheema, H.K., Singh, R., Taggar, G.K., Sandhu, J.S. and Kooner, B.S. 2010. Screening of chickpea genotypes for resistance against gram pod borer, (*Helicoverpa armigera* Hubner) under field conditions. *Journal of Research, Punjab Agricultural University*, **47**: 1-3.
- De Moraes, C.M., Lewis, W.J., Pare, P.W., Alborn, H.T. and Tumlinson, J.H. 1998. Herbivore infested plants selectively attract parasitoids. *Nature*, **393**: 570-573.
- Deshmukh, S.G., Sureja, B.V., Jethva, D.M. and Chatar, V.P. 2010. Estimation of yield losses by pod borer, *Helicoverpa armigera* (Hubner) on chickpea. *Legume Research*, **33**: 67-69.
- Devi, N.S., Singh, O.H., Devjani, P. and Singh, T.K. 2002. Natural enemies of *Helicoverpa armigera* Hubner on chickpea. *Annals of Plant Protection Sciences*, **10**: 179-183.
- Dhillon, M.K. and Sharma, H.C. 2007. Survival and development of *Campoletis chloridae* on various insect and crop hosts: implications for Bt-transgenic crops. *Journal of Applied Entomology*, **131**: 179-185.
- Fitt, G.P. 1989. The ecology of *Heliothis* in relation to agro-ecosystems. *Annual Review of Entomology*, **34**: 17-52.
- Gowda, C.L.L., Ramesh, R., Chandra, S. and Upadhyaya, H.D. 2005. Genetic basis of pod borer (*Helicoverpa armigera*) resistance and grain yield in desi and kabuli chickpea (*Cicer arietinum* Linn.) under un-protected conditions (submitted to *Euphytica*).

- Gowda, D. K. S. and Sharanabasappa Halle, D. 2005. Screening of resistant chickpea genotype for *Helicoverpa armigera* (Hubner). ***Karnataka Journal of Agricultural Sciences***, **18**: 1107-1108.
- Gupta, R., Shukla, B.C. and Kaushik, U.K. 1999. Activity of *Campoletis chloridae* on *Helicoverpa armigera* in chickpea crop as influenced by intercropping with coriander under rice based cropping system. ***Journal of Applied Zoological Researches***, **10**: 32-35.
- Gupta, R.K. and Desh Raj 2003. Extent of parasitism and seasonal activity of *Campoletis chloridae* Uchida in chickpea ecosystem of lower hills of Himachal Pradesh. ***Indian Journal of Plant Protection***, **31**: 5-8.
- Gupta, R.K. and Raj, D. 2003. Natural parasitism by *Campoletis chloridae* Uchida, a promising parasitoid of *Helicoverpa armigera* (Hubner) on chickpea. ***Journal of Biological Control***, **17**: 9-12.
- Hugar, S.V., Sharma, H.C. and Goud, K.B. 2014. Pigeonpea genotypes influence parasitization preference and survival and development of the *Helicoverpa armigera* larval parasitoid, *Campoletis chloridae*. ***Springer Plus***, **3**: 378.
- Kaur, S., Brar, K.S. and Shehmar, M. 2004. Effect of different chickpea cultivars on parasitization of *Helicoverpa armigera* (Hubner) by *Campoletis chloridae* Uchida. ***Journal of Biological Control***, **18**: 69-72.
- Kaur, S., Brar, K.S., Sekhon, B.S., Joshi, N., Shehmar, M. and Singh, J. 2000. Role played by *Campoletis chloridae* Uchida in natural mortality of *Helicoverpa armigera* (Hubner) on chickpea in Punjab. ***Journal of Biological Control***, **14**: 51-54.
- Kranthi, K.R., Jadhav, D.R., Kranthi, S., Wanjari, R.R., Ali, S.S. and Russel, D.A. 2002. Insecticide resistance in five major insect pests of cotton in india. ***Crop Protection***, **21**: 449-460.
- Kumar, L. and Bisht, R.S. 2013. Population dynamics of *Helicoverpa armigera* (Hubner) on chickpea crop. ***Pantnagar Journal of Research***, **11**: 35-38.
- Kumar, S.V.S., Chandraprakash, J., kumar, B.A. and Patil, K. 2013. Screening and clustering of chickpea (*Cicer arietinum* l.) Germplasm to pod borer (*Helicoverpa armigera* Hubner). ***Bioinfolet***, **10**: 513 – 520.

- Leclerg, E.L. 1971. Field experiments for assessment of crop losses. In: *Crop loss assessment methods FAO manual on the evaluation and prevention of losses by pests, diseases and weeds*. Edited by Chirappa, L. 2.1/1.2.1/11.
- Lewis, W.J., Tumlinson, J.H. and Krasnoff, S. 1991. Chemically mediated associative learning: important function in the foraging behavior of *Microplitis croceipes* (Cresson). *Journal of Chemical Ecology*, **17**: 1309-1325.
- Li, Y., Dickens, J.C. and Steiner, W.W.M. 1992. Antennal olfactory responsiveness of *Microplitis croceipes* (Hymenoptera: Braconidae) to cotton plant volatiles. *Journal of Chemical Ecology*, **18**: 1761-1773.
- Mattiacci, L., Dicke, M. and Posthumus M.A. 1994. Induction of parasitoid attracting synomone in *Brussels sprouts* by feeding of *Pieris brassicae* larva: role of mechanical damage and herbivore elicitor. *Journal of Chemical Ecology*, **20**: 2229-2247.
- McAuslane, H.J., Vinson, S.B. and Williams, H.J. 1990. Influence of host plant on mate location by parasitoid *Campoletis sonorensis* (Hymenoptera: Ichneumonidae). *Environment Entomology*, **19**: 26-31.
- Mehta, P.K., Sood, A.K. and Kashyap, N.P. 2000. Loss assessment in chickpea due to *Helicoverpa armigera* (Hb.) in the mid-hills of Himachal Pradesh. *Insect Environment*, **6**: 89-90.
- Munni Lal, Singh, S.V., Dharmendra Singh and Pal, B.N. 2013. Population fluctuations of *Helicoverpa armigera* and *Campoletis chlorideae* and their relationship on chickpea. *Agricultural Science Digest*, **33**: 77-79.
- Pandey, K. and Kumar, P. 2006. Natural parasitization of gram pod bore *Helicoverpa armigera* (Hubner) by insect parasitoid. *Indian Journal of Entomology*, **68**: 410-411.
- Pandey, R. and Ujagir, R. 2009. Effect of intercropping on *Campoletis chlorideae* Uchida, a larval parasitoid of *Helicoverpa armigera* (Hubner) in chickpea. *Journal of Insect Science (Ludhiana)*, **22**: 227-231.
- Pandey, R.K., Singh, G.R. and Tripathi, A. 2005. Role of natural enemies on larval population of *Helicoverpa armigera* on chickpea sown on different dates. *Shashpa*, **12**: 35-37.

- Pawar, C.S., Bhatnagar, V.S. and Jadhv, D.R. 1986. *Heliothis* species and their natural enemies, with their potential for biological control. ***Proceeding of the Indian Academy Sciences (Animal Sciences)***, **95**: 695-703.
- Pawar, V.M. 1998. Microbial control of *Helicoverpa* sp. on pulse crops, pages 55-78 In: *IPM systems in Agriculture* (Upadhyaya, R.K., Mukherji, K.G. and Rajak, R.L. Eds). New Delhi, India, Aditya Books Private Ltd.
- Rai, D., Ujagir, R. and Singh, R.K. 2003. The larval parasitization by *Campoletis chloridae* Uchida (Hymenoptera: Ichneumonidae) of *Helicoverpa armigera* (Hubner) in pure chickpea crop at Pantnagar. ***Journal of Biological Control***, **17**: 81-83.
- Ramegowda, G.K., Rachappa, V., Patil, R.K. and Lingappa, S. 2007. Field screening of chickpea genotypes against *Helicoverpa armigera* (Hubner). ***Journal of Entomological Research***, **31**: 23-27.
- Ramteke, P.W., Simon, S., and David, D. 2014. Population dynamics of *Helicoverpa armigera* infesting chick pea. ***Annals of Plant Protection Sciences***, **22**: 203-204.
- Reed, W., Cardona, C, Sithanatham, S. and Lateef, S.S. 1987. Chickpea insect pests and their control. The Chickpea (Eds: Saxena, M.C. and Singh, K.B.) CAB International Wallingford, Oxon, U.K., 283 - 318 pp.
- Romeis, J. and Shanower, T.G. 1996. Arthropod Natural Enemies of *Helicoverpa armigera* (Hubner) (Lepidoptera: Noctuidae) in India. ***Biocontrol Science and Technology***, **6**: 481-508.
- Sachan, J.N. and Bhaumik, R. 1998. Extent of parasitization of *Campoletis chloridae* - a larval parasite of *Helicoverpa armigera* damaging chickpea. ***Indian Journal of Pulses Research***, **11**: 65-69.
- Sachan, J.N. and Katti Gururaj 1994. Integrated Pest Management. In Souvenir: 25 years of research on pulses in India, International Symposium on Pulses Research held on April 2-6, 1994 at IARI. New Delhi, Pp 23-26.
- Sandhya, S.R. and Chandekar, P.P. 2010. Screening of chickpea genotypes against pod borer, *Helicoverpa armigera* (Hubner) under field and in laboratory conditions. ***Green Farming***, **1**: 329.

- Sharma, H.C., Pampapathy, G. and Sullivan, D.J. 2003. Influence of host plant resistance on activity and abundance of natural enemies. In: *Biological control of insect pests* (Ignacimuthu, S. and Jayaraj S. eds) New Delhi, India: Phoenix Publishing House, pp 282-296.
- Sharma, H.C., Ahmad, R., Ujagir, R., Yadav, K.P., Singh, R. and Ridsdill-Smith, T.J. 2005. Host plant resistance to cotton bollworm/legume pod borer, *Helicoverpa armigera*, pages 167–208. In *Heliothis/Helicoverpa Management: Emerging trends and strategies for future research* (Sharma, H.C. Eds) New Delhi, India: Oxford and IBH Publishing Inc.
- Singh, C.B., Srivastav, A.K. and Rai, M.K. 2008. Survey and assessment of status of *Helicoverpa armigera* in district Jhansi on chickpea. *Indian Journal of Entomology*, **70**: 113-117.
- Singh, R. and Ali, S. 2006. Seasonal incidence of *Helicoverpa armigera* and *Campoletis chlorideae* on chickpea. *Annals of Plant Protection Sciences*, **14**: 234-235.
- Sithanatham 1987. Insect pests of pigeonpea and chickpea and their management, pages 159- 173. In: *Plant Protection in Field Crops* (Veerabhadra, Rao M. and Sithanatham, S. Eds). Hyderabad, Andhra Pradesh, India: Plant Protection Association of India.
- Srivastava and Srivastava, 1990. Estimation of avoidable loss in chickpea (*Cicer arietinum*) due to gram-pod borer (*Heliothis armigera*) in Rajasthan. *Indian Journal of Agricultural Sciences*, **60**: 494-496.
- Tian, S.P., Zhang, J.H., Yun-Hua Yan Y.H., and Wang, C.Z. 2008. Interspecific competition between the ichneumonid *Campoletis chlorideae* and the braconid *Microplitis mediator* In their host *Helicoverpa armigera*. *Entomologia Experimentalis Applicata*, **127**: 10–19.
- Tumlinson, J.H., Turlings, T.C.J. and Lewis, W.J. 1993. Semiochemically mediated foraging behavior in beneficial parasitic insects. *Archives of Insect Biochemistry & Physiology*, **22**: 385-391.

- Turlings, T.C.J. and Tumlinson, J.H. 1992. Systemic Release of chemical signals by herbivore injured corn. *Proceedings of the National Academy of Sciences U S A*, **89**: 8399-8402.
- Turlings, T.C.J., Loughrin, J.H., McCall, P.J., Rse, U.S.R., Lewis, W.J. and Tumlinson, J.H. 1995. How caterpillar damaged plants protect themselves by attracting parasitic wasps. *Proceeding of the National Academy of Sciences U S A*, **92**: 4169-4174.
- Turlings, T.C.J., Scheepmakeer, J.W.A., Vet, L.E.M., Tumlinson, J.H. and Lewis, W.J. 1990. How contact foraging experiences affect preferences of host related odours in the larval parasitoid, *Cotesia merginiventris* Cresson (Hymenoptera: Braconidae). *Journal of Chemical Ecology*, **16**: 1577- 1589.
- Udayagiri, S. and Jones, R.L. 1992. Flight behavior of *Macrocentrus grandii* Goidanich (Hymenoptera, Braconidae), a specialist parasitoid of *European corn borer* (Lepidoptera, Pyralidae)-factors influencing response to corn volatiles. *Environment Entomology*, **21**: 1448-1456.
- Ujagir, R. 2005. Screening of chickpea (*Cicer arietinum*) genotypes for resistance to gram pod-borer (*Helicoverpa armigera*). *Indian Journal of Agricultural Sciences*, **75**: 120-122.
- Vaishampayam, S.M. and Veda, O.P. 1980. Population dynamics of gram pod borer *Helicoverpa armigera* in chickpea at Pantnagar (UP). *Indian Journal of Plant Protection*, **15**: 39-41.
- Vet, L.E.M. and Groenewold, A.W. 1990. Semiochemicals and learning in parasitoids. *Journal of Chemical Ecology*, **16**: 3119-3135.
- War, A.R., Sharma, H.C., Paulraj, M.G., War, M.Y. and Ignacimuthu, S. 2011. Herbivore induced plant volatiles- their role in plant defense for pest management. *Plant Signaling and Behaviour*, **6**: 1973-1978.
- Whitman, D.W. 1988. Allelochemical interaction among plants, herbivores and their predators.in: Barbosa, P. and Letourneau, D.K (eds) Novel aspects of insect-plant interaction. Wiley, New York, pp 11-64.

